PROGRESSIVE FARMING

THE MAINTENANCE OF HIGH PRODUCTION

Written by a Team of Contributors and Edited by

J. A. HANLEY

A.R.C.S., Ph.D.

Formerly:—Professor of Agriculture and Rural Economy, King's College, Newcastle-on-Tyne (University of Durham); Professor of Agriculture and Chief Advisory Officer, University of Bristol; Principal of Royal Agricultural College, Cirencester; Minister of Agriculture's Liaison Officer with Northern Counties, 1940–47.

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LIST OF CONTRIBUTORS

TO

PROGRESSIVE FARMING

G. W. ROBINSON, C.B.E., Sc.D., F.R.S.
Professor of Agricultural Chemistry, University College of North Wales, Bangor.

R. STEWART, B.Sc., Ph.D.
Chief Adviser, Messrs. Fisons Ltd.

D. H. ROBINSON, Ph.D., B.Sc., N.D.A.
Formerly: Lecturer at Harper Adams Agricultural College, Newport, Shropshire.

D. A. OSMOND, M.Sc., Ph.D.
Deputy Chief of Soil Survey of England and Wales.

A. H. HOARE
A specialist in Horticultural Crops.

E. W. HOBBIS, B.Sc., N.D.H.
Plantations Officer, Long Ashton Research Station, University of Bristol.
Formerly: Horticultural Advisory Officer for Worcestershire and Monmouthshire.

F. H. BEARD, Hort. Dip. (Wye)
In charge of Hop Investigations, East Malling Research Station, Kent.

R. ALUN ROBERTS, B.Sc., Ph.D.
Professor of Agricultural Botany, University College of North Wales, Bangor.
Formerly: Advisory Officer in Agricultural Botany, Executive Officer W.A.E.C., Carnarvonshire, 1940–44.

E. J. ROBERTS, M.A., Dip. Agric. (Cantab.), M.Sc.
Professor of Agriculture, University College of North Wales, Bangor.
Formerly: Professor of Agriculture, University College of Wales, Aberystwyth.

F. R. HORNE, M.A., N.D.A., N.D.D.
Director of National Institute of Agricultural Botany, Cambridge.
Formerly: Head of Botany Department, Seale-Hayne Agric. College, Devon.
Chief Technical Officer, Devon W.A.E.C., 1941–44.

L. OGILVIE, M.A., B.Sc. (Aberdeen), M.Sc. (Cantab.).
Advisory Plant Pathologist, South West Province National Agricultural Advisory Service.

E. HOLMES, Ph.D., M.Sc., F.R.I.C.
Head of Technical Department, Plant Protection, Ltd.

G. E. BLACKMAN, M.A.
Sibthorpian Professor of Rural Economy, Department of Agriculture, University of Oxford.

L. C. LUCKWILL, B.Sc., Ph.D.
Research Pomologist, Long Ashton Research Station, University of Bristol.
Formerly: Assistant Lecturer in Botany at the Universities of Manchester and Aberdeen.

J. E. NICHOLS, M.Sc., Ph.D., F.R.S.E.
Professor of Agriculture (Animal Husbandry), University of Wales, Aberystwyth.
Formerly: Hackett Professor of Agriculture, University of Western Australia.
Director, Imperial Bureau of Animal Breeding and Genetics, Edinburgh.

S. J. WATSON, D.Sc., F.R.I.C., F.R.S.E.
Professor of Agriculture and Rural Economy, Edinburgh University. Principal of Edinburgh and East of Scotland College of Agriculture,
Formerly: at Jealotts Hill Agricultural Research Station of Imperial Chemical Industries, first as Head of Section of Biochemistry and Animal Nutrition, later Head of Laboratories and in charge of Agricultural Research Station. Also at King's College, Newcastle-on-Tyne, Cheshire School of Agriculture, East Anglian Institute of Agriculture.

List of Contributors

H. S. HALL, B.Sc.
Head of Dairy Engineering Department, National Institute for Research in Dairying, Shinfield, Reading.

A. W. ANDERSON, O.B.E., B.Sc.
Formerly: A Senior Marketing Officer of the Ministry of Agriculture and Fisheries and in charge of Slaughterhouse Organisation in the Ministry of Food during control.

ELWYN JONES
Breeder of pedigree Hereford cattle. Judge of beef cattle (Herefords) in Argentina 1946 and 1947. Member of Breconshire W.A.E.C. and Chairman of their Livestock Committee.

W. R. SEWARD, N.D.A.
Principal of Chadacre Agricultural Institute, Bury St. Edmunds.

K. W. D. CAMPBELL, M.C., M.Sc. (Reading), B.Sc. (Dur.).
Formerly: Farm Director and Head of Agricultural Department, Harper Adams College. Lecturer in Agriculture, Reading University. Livestock Officer to Land Settlement Association.

HERBERT HOWES
Assistant Director, National Institute of Poultry Husbandry, Newport, Shropshire.

T. DALLING, M.A., M.R.C.V.S., F.R.S.E.
Chief Veterinary Officer, Ministry of Agriculture and Fisheries.
Formerly: Professor of Animal Pathology, University of Cambridge.

A. THORPE, F.R.I.B.A.

H. M. HUGHES, A.I.B.A.E.
Editor "Farm Mechanization" and "British Farm Mechanization."

A. C. WILLIAMS, A.I.B.A.E.
Assistant Editor "Farm Mechanization" and "British Farm Mechanization."

G. S. BROWNE, B.Sc. (Econ.)
Director of Intelligence of "The Economist."
Formerly: Head of Economics and Statistics Department, National Farmers' Union Headquarters. Member of United Kingdom Farmers' Delegation 1944–45 to New Zealand, Australia, Canada and U.S.A.

EDGAR THOMAS, B.Litt., B.Sc.
Professor of Agricultural Economics, Reading University.

PREFACE

The establishment of the National Agricultural Advisory Service and the expansion of the schemes providing technical advice for farmers seem to call for some means of bringing together in one comprehensive account the many farming practices that were developed from 1939 onwards and which helped to bring about those all-round increases in productivity so evident in recent years.

The present book is an attempt to do this and at the outset the plan was considered with Professor J. A. Scott Watson, Director of the National Agricultural Advisory Service, to whom the Editor's thanks are due for valuable help and advice.

At various times the scope of the book has been discussed with prominent farmers, and particular thanks are due to Mr. Dennis Brown, West Learmouth, Cornhill-on-Tweed, for many helpful suggestions.

The book has been written primarily for farmers. The first fifteen chapters deal with crop husbandry, four of them with the more intensive crops: fruit, vegetables and hops. It is not easy to draw the line between farm and market-garden crops, but it is important that a proper lead should be given to the many farmers who are now venturing into this more intensive field. Here advantage has been taken of valuable help from Professor T. Wallace, Director of the Long Ashton Research Station, Bristol University, who advised on the arrangement and contents of these chapters.

The second half of the book deals in the main with livestock, and the Editor is much indebted to Professor J. E. Nichols, of Aberystwyth, for help and advice on the livestock chapters.

But there are other factors besides supplies of fertilisers and feeding-stuffs that influence the productivity of farms. Some of these are dealt with in the concluding chapters, and amongst them are: facilities for housing and handling the produce of crops and livestock; the general layout of the farm and farm buildings on which the health of livestock and the quality of produce depends and, finally, the encouragement a far-seeing national agricultural policy can promote.

In acknowledging assistance in the preparation of the book the Editor wishes to thank the twenty-eight contributors for their loyal collaboration throughout and also the many people who have allowed us to reproduce some excellent photographs.

J. A. Hanley,
Editor.

FOREWORD

By The Rt. Hon. Tom Williams, M.P.
Minister of Agriculture and Fisheries

Never since the "hungry 'forties" of last century has it been so important as it now is that we should quickly and largely increase production from our all-too-few acres of farm land.

Our present man-power resources are small compared with those of a century ago, and we must therefore make full use of the advantages in other respects that we enjoy. These are not small; we have more and better machines, vastly greater supplies of fertilisers, far better types of crop plants and livestock; and, above all, we have infinitely more knowledge.

This book, containing as it does full and up-to-date technical information on agriculture, has thus appeared at a very appropriate time. I am glad that Professor Hanley has been able to carry through the heavy task of planning and editing it.

He has been able to get together a team of leading authorities on the various aspects of the subject, and has welded their contributions into a comprehensive whole.

The book will clearly be of great service to agricultural advisers and teachers, but above all it is to be hoped that it will find a place among the farmers' "tools."

T Williams

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Colour Plate

INTRODUCTION

By SIR JAMES TURNER, *President of the National Farmers' Union*

THE aspects of farming which are dealt with in subsequent pages would have been prominent in any case with the normal development of agriculture after the storm and stress of war but they have acquired even greater importance and prominence since all relate to essential factors in the achievement of the Agricultural Expansion Programme. It will be recalled that this blue-print of agricultural production was part of the general Four-Year Programme for Recovery published in December 1948. The first edition of the agricultural plan was, in fact, published by the Minister of Agriculture in August 1947, and it called upon farmers to resume their war-time task. The specific measures for achieving the Programme enumerated in the Government's White Paper read like some of the chapter headings in this book—a happy coincidence for a book designed as a contribution to agricultural improvement. It is only by the adoption of new methods and by increasingly skilled technique that farming is able to meet the heavy demands now made upon it.

The task set for agricultural producers by the 1952-53 targets is a formidable enough measure in terms of increased output alone. The aim is an output not less than 50 per cent. higher than it was before the war. The real extent of the effort involved, however, can only be measured by taking into account also the long strain undergone by the industry since 1939, and the shortages, the improvisations and the frustrations which have been the constant experience of farmers during these recent war years.

During the pre-war years of depression farm production had fallen, but the potential was there. When supplies from abroad were restricted by war, the farmer assumed his rightful place in the nation's economy—as producer of the nation's food. During those war years the farmers played an ever increasing part in feeding the besieged population of this island. Production from our own soil was increased considerably and in 1944 we produced at home nearly one half of all the food we consumed—measured by any standard.

The basis of this remarkable achievement was the bringing into arable cultivation of six million acres of permanent grassland; this expansion was achieved in spite of the withdrawal from agriculture of thousands of acres mostly from the best arable areas for aerodromes and other defence works. Such an increase in the tillage acreage, of roughly 50 per cent., was enough to change the whole pattern of farming and also the relationship of farm production to the nation's economy as a whole.

Linked to this vast plough-up were the triple pillars of the output plan—increased acreages of the staple foods, wheat and potatoes; a decrease in the production of most livestock and livestock products which competed with humans for feed from our limited acreage; and a concentration on milk production for direct consumption in the interests of health and a balanced diet. In fact, the wheat and potato acreages were doubled, enabling us to produce almost half of our flour needs at home and, though the pig and poultry population dropped considerably, the number of dairy cows actually increased.

Most of the more detailed problems which accompanied this change are well known, both to farmers and to those who live in the towns. Labour was one, mechanisation was another, supplies of animal feeding-stuffs and artificial manures from abroad were others. Perhaps the greatest problem was the human one of introducing the changes which the war necessitated, with all the accompanying difficulties which war-time shortages and restrictions imposed. This was the farmer's own problem, and it differed in degree and content in every part of the country.

The degree of increased output was not the same in every county. Those with a high proportion of grassland before the war completely changed their farming systems. The traditionally arable regions were mainly concerned in intensifying production. The big changes which took place in many counties are often overlooked when the overall achievements of farming are spoken of. For the farmers concerned they meant great investment in new equipment and the mastery of new techniques. In this they were ably assisted by the Advisory Officers of the W.A.E.C.s, who put at their disposal the latest information relating to the new crops which they were growing.

It is important to note how the stimulus of urgent war requirements led to a number of developments in fresh directions and in the improvement of existing farming practices. Among the most interesting was the large increase in the flax acreage that was, of course, a direct outcome of military needs; with the end of the war the acreage dropped considerably. The experience of growing flax for fibre was, however, turned to good account when the demand for linseed, both for commercial purposes, and as a valuable constituent in concentrated feeding-stuffs, demanded a greatly increased acreage under this crop. A very important development has been that of home seed production. The country had allowed itself during the period between the wars, to become almost entirely dependent upon overseas sources of supply for stocks of many essential seeds. During and since the war, a young and healthy home industry has been built up, and there is no reason why it should not progress further, always provided it is not ruined by unrestricted imports from overseas.

The drastic curtailment of imports of feeding-stuffs in war-time has, in modified form, become, for currency reasons, a long-term policy. The

planning for a higher standard of self-sufficiency in feeding-stuffs than was the case in pre-war days when imports were practically unlimited, is an essential feature of the farm cropping programme.

Possibly the most spectacular development has been in the mechanisation of farming. The difficulties of manpower have led to an expansion of agricultural machinery production which would have been much greater had it not been for the industrial difficulties of manpower, steel scarcity and the imperative need for maintaining exports of machinery. The foundations were laid during the war for the extension of artificial insemination of cattle, a development which may have a profound effect upon the future of our dairy husbandry in particular. Already this new breeding technique has revolutionised methods and ideas in cattle breeding. Silage making, grass and grain drying, the use of the combine harvester, not to mention notable advances in veterinary science, are but a few of the other outstanding instances where development has been stimulated under war conditions or on account of the economic stringency that has followed.

In some respects, the farmer's record of production since the end of the war is even more remarkable than his war effort. During the war there was at least certainty of what was required—a limitless demand for agricultural products at all costs. It was the urgency of the need for food that led to the introduction of detailed cropping programmes. Cropping direction of farmers naturally led to some heart-burning and sharp differences of opinion here and there, but on the whole it speaks volumes for the tolerance and good sense of both farmers and War Agricultural Executive Committees that so difficult and unprecedented an interference with individual farm organisation was carried out with relatively little friction. With the end of the war there was naturally a desire by farmers to be free from direction. In 1947 the Government announced that it was not its intention to seek the authority of Parliament for securing the targets of 1948 by special directions, but the power to direct remains in the Minister's hands.

The end of the war lessened the sense of urgency and gravity; the momentum of effort tended to slacken with the hope of some readjustment to a peace-time footing. These hopes were shortlived. The economic crisis and a world food shortage put an end to any ideas of a relaxed effort. Instead of the hoped-for switch-over to normal cropping, there was fresh urgency to bring the machinery of production into top gear once more. This happened at the very time when agriculture became subjected to all the uncertainties of supplies and labour which were direct consequences of the economic "blitz." In mentioning these uncertainties which added to the problems of the post-war period, it is only right to say that the institution of the policy of assured markets and guaranteed prices for the principal agricultural commodities and the yearly adjustment at

the February Price Review have proved a stabilising factor amid the problems of the post-war period.

Progress in farming methods comes through the practical application of scientific discovery and, despite very considerable progress in bringing the Agricultural Research Stations into closer contact with practical farming, there is still room for improvement in "advising experienced farmers on the means to be adopted in applying scientific discoveries to practice." Readers of this book cannot fail to be impressed with the extent to which every aspect of farming practice offers scope for the research worker and the agricultural adviser. Recent developments in the extension of the work of Research Stations by the setting up of experimental husbandry farms and horticultural stations, have as their object the raising of the general standard of farming efficiency. Between the research worker and the farmer there has to be a link. Concurrently therefore, the recent constitution of the National Agricultural Advisory Service has provided a means through which qualified officers supply farmers with the best technical advice on the practical application of the latest results of scientific and technical research. It should be added that agriculturists are responsive to the proferred help which these developments in agricultural research and education give, and there has never been a time when the demand for the written and spoken word on agricultural improvement was more evident.

We are slowly, but surely, progressing towards economic recovery as a nation, and there is good evidence that the farmer is making a very considerable contribution towards the national effort to win the peace. We are strengthening our financial weakness with wealth obtained from the productive capacity of our land. There can be no relaxing yet by farmers in this battle for food, and no slackening of progress in farming efficiency. It is to that end that the following chapters have been written by technical experts, each one a well-known authority in his particular subject.

PROGRESSIVE FARMING

VOLUME I

CHAPTER I

SOILS

By G. W. Robinson

The soil is the foundation of all agriculture and, indeed, of all human life. Success in farming, however much it may depend on wages, prices, and economic factors, ultimately depends on the kind of soil the farmer has to deal with and on the use he makes of it. Just as some animals are "good doers" and give a good return in meat or milk, so some soils are more fertile than others and give a better return for the farmer's efforts. There are differences even among those soils that all farmers would call fertile. One soil may carry first-class grazing, another may be highly productive for potatoes, another for barley, and so on. The purpose of the present article is to try to explain how soils are made up, in what respects they differ from each other, and what is meant by soil fertility.

If a farmer were thinking of taking a new farm he would want to know something about the soil. For this purpose it would not be sufficient simply to have samples of the soil in small bags sent to him by post. To be sure, if he looked at these samples, he might be able to get a rough idea as to whether the soil is sand, loam, or clay. And if he took the samples along to the soil chemist he might be told how each sample stood for lime, phosphate, and potash. But even supposing that he had found out that the soil was a nice medium loam and that it had sufficient lime, phosphate, and potash it would not follow that it would be a good soil, because *on the farm* this particular soil might have a heavy clay subsoil and suffer from poor drainage, or have a coarse gravelly subsoil and suffer from drought. Or it might be on a steep hillside which could not be cultivated. The soil must be judged on the spot, for there is all the difference in the world between soil *as a material* in a bag and soil as it occurs *in the field*. And it is soil in the field that we must discuss in this article.

THE FORMATION OF SOILS

Ultimately, every soil traces back its ancestry to rock. The only exceptions are peats, which are formed from decomposed plant remains. Everywhere the soil is underlain by rock. In some parts of the country, as in much of Wales and the Lake District, the rock is not far from the surface, and in some places may even stick up through the soil. In other districts, such as South-East England, the rock may be deep down. Also, there are many different kinds of rock. It may be hard granite or slate,

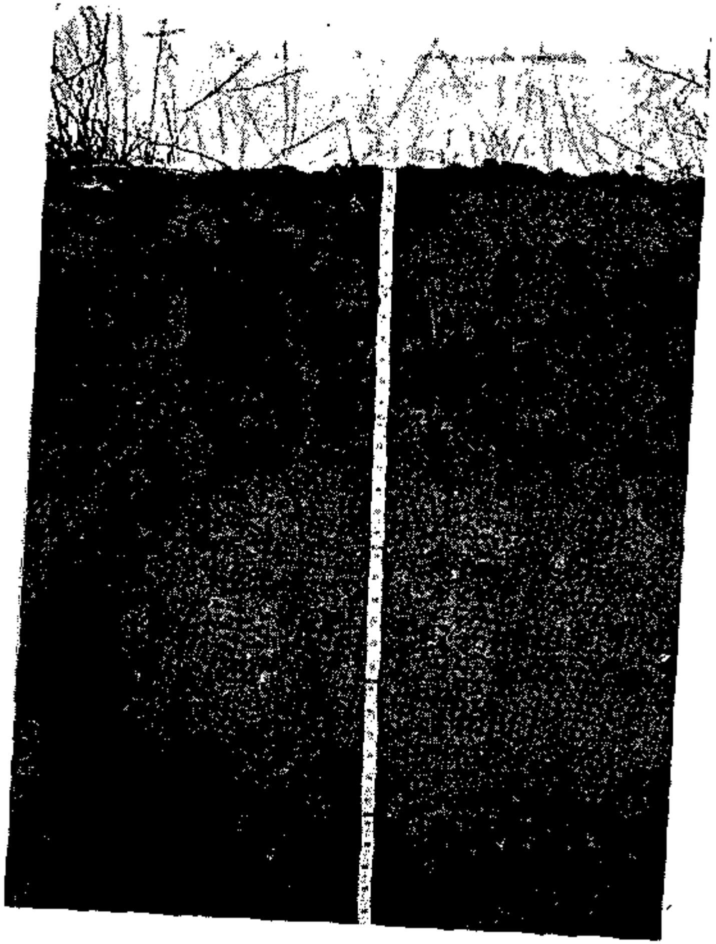
it may be hard limestone, it may be soft chalk, or it may even be soft sandstone or clay. Some of the materials that the geologists call rock would hardly be called rock at all in ordinary speech. Now all these rocks undergo decay when exposed to weather. This can be seen quite well in the stones of old churches and castles. It can be seen also, particularly in churchyards, that some stones weather more quickly than others. We need not go deeply into the way in which this decay or weathering takes place, but heat and cold, frost and thaw, and the gradual rotting of rocks when in contact with moisture, particularly with moisture that has soaked through the soil, all play a part.

Near to Shrewsbury is the old Roman city of Viroconium. It once covered some hundreds of acres, but today, except where it has been uncovered by excavations, fields of corn and grass hide what was once a Roman city. Actually, the city lies buried under its own ruins, from which the present soil has been formed. So the rocks of the earth lie buried under their own ruins. But nature does not let these ruins accumulate indefinitely. Rain washes soil downhill, and in times of flood, rivers run turbid with material washed into them from the surface of the soil. This material is carried by the rivers; some of it is deposited during floods as alluvium along their lower courses, whilst some gets to the sea and forms the deposits of sand and mud in estuaries. In the course of millions of years the material carried by rivers and deposited on the bed of the sea gets compressed and hardened to form new rocks. Sandstones and shales are examples of such rocks.

Material can be carried also by wind. This can be seen in the sand-dunes round our coasts. Across Europe and Asia and in North America there are deep deposits of very fine loam that have been built up from dust carried by the wind. This transport of material by wind can sometimes be disastrous, as in the Dust Bowl of North America where, about ten years ago during great droughts, whole farms went up in dust which was carried across the country as far as the Atlantic Coast.

Finally, we must mention glaciers. Tens of thousands of years ago much of northern Europe and North America was covered by great sheets of ice. Most of Great Britain north of the Thames was thus covered. During the Ice Ages the existing soil was scraped away, the surface of the underlying rocks was worn down, and the material carried along with the ice, generally towards the south, where the glaciers melted away. When the last Ice Age passed away, the country formerly covered by ice was left bare of vegetation with a mantle of varying thickness of stony clay, called *boulder clay* or *till*. Streams from the melting ice washed over the surface of this and from these streams were deposited beds of gravel, sand and silt. Then the vegetation returned and a cover of soil was gradually built up.

If a hole or trench is dug in a field we find first the top-soil, in which are most of the roots of plants, then the subsoil which resembles the



Deep loamy soil over clay-loam subsoil.
(*Photo by C. E. Kellogg.*)

Shallow stony loam over rock.
(*By courtesy of R. E. Hughes.*)

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top-soil, but is generally lighter in colour and often heavier in texture, and below the subsoil raw clay, sand, or in some cases decaying rock, passing to the rock itself. And here we see how soil in the field differs from a sample of top-soil. It matters very much what lies under the surface and, therefore, when we think of a soil we must think of the top-soil and what lies below it. The term *soil profile* is used to denote the complete succession of layers from the top-soil down to the raw stuff or rock lying perhaps 3 or 4 feet below the surface. In Plate facing page 2 we see some pictures of actual soil profiles.

To return to the formation of soils. How is the raw stuff—clay, sand, or decaying rock, turned into soil? The process can be seen going on at the present day on the sloping sides of road cuttings and railway embankments and wherever raw subsoil is exposed. Weed plants and coarse grasses establish themselves and increase, until finally the raw stuff gets completely covered with vegetation. At a later stage, bushes and trees may appear. As each year's growth dies down the remains get mixed in with the surface layer and in time a thin soil is formed. In land that has never been cultivated, like parts of the New Forest and Sherwood Forest, this process has been going on since the end of the last Ice Age, and the surface soil is rich in decomposed vegetable matter from leaf fall and ground vegetation. This decomposed vegetable matter in soils is called *humus*.

The decomposition of dead vegetable matter is carried out by the action of fungi and bacteria, which swarm in the soil in countless numbers. The change is assisted also by the action of earthworms and insects, which break down the dead plant material and mix it with the soil. An example of this is the way in which grass cuttings disappear from the surface of a lawn after it has been mown.

Other changes take place as the amount of humus in the soil increases. The surface soil, instead of lying close like clay or sand, becomes granular and spongy. Raw sand or clay exposed to rain "beats" together so that pools lie on the surface; but soil, especially when freshly cultivated, absorbs the rainfall rapidly because of its spongy structure. This structure means also that air is let into the soil; and air is very necessary for the health of the soil and for the roots of the plants growing on it.

Most of our agricultural soils were formed many hundreds of years ago under virgin forest, scrub, swamp, or grassland. During the centuries they have been altered quite a lot by man, but retain many of their original characters. In some cases, however, the cultivator can alter a soil very greatly. For example, some of our richest market garden soils were originally poor and sandy, but have been built up to a high state of productivity by repeated heavy dressings of farmyard manure; the rich soils of the Fens were once waterlogged peat; and large areas of wet clay carrying rushes and grass have been changed by drainage and management into high-grade pastures.

In our own country, on the whole, the effect of man's efforts in bringing

virgin lands into cultivation has been to build up the fertility of the soil. In some countries the reverse has been the case. For example, in vast areas of the United States, virgin forest was brought under the plough and cropped year after year until its fertility was exhausted and its stock of humus worn away. We have been spared such losses in our own country, partly because our rainfall does not come down in such intense falls and partly because our summers are not so hot, with the result that the humus in the soil does not "burn out" so badly.

There are other changes in the formation of soil from its raw material. In our wet climate the soil is continually being washed by the rain. The annual rainfall in Great Britain varies from less than 20 inches in certain parts of the east coast to about 200 inches in the highest mountains of Wales and Scotland. Over most of the country it is about 25 to 30 inches. What happens to this rain? Let us suppose the rainfall to be 30 inches. About half of this is either used by crops or evaporates off from the surface of the soil. The remainder sinks down through the soil and finds its way into the deeper subsoil, eventually coming out through springs into brooks and rivers, and so to the sea. Now 1 inch of rain means about 100 tons per acre, so that each acre of soil has about 1,500 tons of water sinking down through it in the course of the year. This drainage water dissolves certain constituents from the soil. One of the most important of these constituents is lime and the annual loss of lime from the soil is from 1 to 5 cwt. per acre, the higher figure being found where the soil is rich in lime. From this we see that unless the material from which the soil has been made is rich in lime, it eventually gets impoverished in this constituent and the losses have to be made good by dressings of lime, chalk, or ground limestone. Where the soil is originally poor in lime and where no lime is applied in dressings, the soil becomes very sour and infertile. Another constituent lost in the drainage is nitrate. Losses of nitrate may be considerable during the autumn months if the rainfall is heavy.

An important factor affecting the character of the soil is the ease or otherwise with which the drainage water passes through the soil. In some low-lying situations water is always standing near the surface. Sometimes the subsoil is a heavy clay and the rainfall cannot sink in. Then the soil becomes waterlogged during the wet season so that it cannot be cultivated. Such soils often suffer from drought during the summer because the roots of crops or grass are confined to the top few inches. Soils with poor drainage are generally grey in colour and show characteristic rusty streaks or mottlings which are evident, even when they dry out. In extreme cases, peat may form at the surface. Naturally, the higher the rainfall, the more frequent will be the occurrence of poorly-drained soils. In the drier south and east poorly-drained soils are generally found only in low-lying situations in the bottoms of valleys, but in the wetter climate of the north and west such soils may be found even in the uplands.

SOIL AS A MATERIAL

In order to understand the nature and properties of the soil in the field we must know something of the properties of soil considered *as a material.* A knowledge of these properties enables us to follow the vertical variations in the successive horizons that make up the soil profile. In a single soil profile the character of the material varies considerably as we go from the surface downwards.

Texture.—The first and most important property of soil is its *texture.* When a farmer speaks of a heavy soil, a medium soil, or a light soil he is speaking of its texture. What determines the texture of the soil? Principally, the relative proportions of coarse and fine particles in it. In the field, the soil consists of particles varying in size from stones, through gravel, sand, and silt down to the very finest particles which are termed "clay." When the soil is examined in the laboratory it is usual to screen out the particles of gravel and sand above 1/12 inch (2 mm.) in diameter and use the material finer than this for analysis. If the proportion of gravel and stones amounts to 10 per cent. or more, the soil is definitely gravelly or stony. In some soils the proportion may reach to as much as 50 per cent. as in some soils of mountainous regions and in certain river gravels.

Now, just as potatoes can be separated by screens into ware, seed, and chats, so on a much smaller scale the soil chemist can find out the percentage of each of a number of fractions in the soil. In this country, and in most countries, four fractions are recognised, namely: coarse sand, fine sand, silt, and clay. Just as different grades of potatoes are defined by the size of screen, so soil fractions are defined by their effective diameters. Here they are approximately:

Coarse sand between 1/12 inch and 1/120 inch (2 mm. to 0.2 mm.)
Fine sand „ 1/120 inch and 1/1,200 inch (0.2 mm. to 0.02 mm.)
Silt „ 1/1,200 inch and 1/12,000 inch (0.02 mm. to 0.002 mm.)
Clay less than 1/12,000 inch (0.002 mm.)

It should be added that sieves cannot be used for separating the soil below 1/120 inch, so a special method must be used, depending on the settling of the soil particles suspended in water.

Now to see how texture is reflected in the relative percentages of these different fractions, let us take the figures for some typical soils. Here they are:

	Coarse sand per cent.	Fine sand per cent.	Silt per cent.	Clay per cent.
Sandy soil	66	18	5	8
Light loam	27	30	20	19
Medium loam ..	9	43	23	21
Heavy loam	14	17	25	35
Clay soil	1	7	21	66
Heavy clay soil ..	1	4	8	83

These are just typical figures and show what are likely figures for each of the textures mentioned. For example, some clay soils may contain only 45 to 50 per cent. of clay and correspondingly more silt and sand. Another point to notice is that the figures do not add up to 100 because, in addition to the fractions, coarse sand, fine sand, silt, and clay, there is also present in the soil, organic matter or humus. This soil organic matter or humus is such an important constituent that we shall have to give a separate section to it; but first we must say something about the mineral part of the soil, namely the stones, gravel, sand, silt, and clay.

Stones and Gravel.—By these terms we understand the larger-sized fragments of rock present in varying proportions in soils. Some soils, particularly in mountain and hill districts, but also in some lowland districts, may contain considerable proportions of gravel and sand, running up to stones or boulders large enough to affect cultivation. Medium-sized stones and gravel in moderate proportions are probably beneficial as they facilitate drainage. They may also check losses of moisture by evaporation during drought. In excess, however, they may interfere with cultivation.

Sand.—There is no hard and fast line between gravel and sand, but fragments less than 1/12 inch diameter are generally considered as sand. Sand as a soil constituent generally consists mainly of fragments of quartz, but in some of the soils derived from hard ancient rocks it may be gritty or shaly. A good proportion of sand gives the soil a light texture and favours drainage and aeration. It is poor in plant food and very sandy soils tend to be hungry. Sand has a low capacity for holding moisture.

Silt.—This term is applied to the particles intermediate in size between sand and clay. Silt is richer in reserves of plant food than sand, and although a high proportion of silt may tend to make the soil too compact, a moderate proportion is beneficial in giving "body" to the soil and increasing its capacity for holding moisture.

Clay.—As a soil constituent, clay consists of the finest particles. It differs markedly in composition and properties from sand and silt. Particles of sand and silt, if examined under a microscope, will be found to consist mainly of material present in the original rocks from which the soil has been formed. If a hard rock such as granite or slate were ground down to the finest powder it would still lack the characteristic properties of clay. Clay is different, and is formed from the chemical weathering of rocks. The properties of clay are so important for the soil that they must be briefly reviewed.

(1) Clay has a great capacity for absorbing moisture. In absorbing moisture it swells, and on drying shrinks. Those familiar with clay land will have noticed the large cracks that form at the surface, particularly in pastures, in drought.

(2) Clay is plastic when wet. A soil which contains a considerable

proportion of clay can be moulded like putty when wet. The way in which a clay soil "pastes" when worked in a wet condition is familiar to every farmer of heavy land.

(3) Clay gives to the soil the property of setting to hard clods when it dries after being ploughed wet. Whilst this cohesion is a disadvantage when it leads to the formation of big unworkable clods, it is also an advantage in so far as it enables the soil to form aggregates or crumbs, in other words to have what the farmer calls "tilth."

(4) Clay absorbs certain constituents from fertilisers and thus acts as a sort of storehouse of plant food in the soil.

HUMUS

Perhaps the most important difference between raw subsoil and soil is that soil contains *humus*. Humus is a constituent of the soil formed from the decomposition of plant material and, to a lesser degree, animal material added to the soil. Let us see what happens in a forest. Each year leaves fall to the ground. This takes place in the autumn with deciduous trees like oak, beech, and ash, and during the growing season with evergreen trees like pine, spruce, and holly. The various plants forming the ground vegetation also die down in the autumn. So each year a supply of dead vegetable matter gets returned to the surface of the soil. This undergoes decay, and the decay is mainly due to the work of different kinds of fungi. In this way leaf-mould is formed on the surface of the forest soil. If, as is generally the case, earthworms are present, the leaves get drawn into the soil and undergo further change. On the other hand, in some coniferous forests very few earthworms are present, and a matted layer of "raw humus" accumulates on the surface. We can see the same kind of raw humus mat on the surface of some sour pastures. The decomposed vegetable matter in the soil is called humus and in most ordinary soils forms 5 to 10 per cent. of the total weight of soil. In peat soils the proportion of humus is higher. Some peats consist entirely of humus. Of course, both in ordinary soils and peats there is always a certain amount of vegetable matter that has not yet been completely decomposed.

The processes going on in ordinary soils are very similar to those in forest soils. Take the case of a cornfield. After harvest the dead stubble and roots remain behind in the soil and the straw eventually comes back to the soil in the farmyard manure together with the excreta of farm animals. In grassland, a considerable proportion of each year's growth dies down and a lot of it also gets returned to the soil in the droppings of grazing animals.

Humus resembles clay in many ways, most of all in the capacity for retaining moisture. Unlike clay, it does not make the soil plastic or sticky, but rather helps to make clay soils more mellow and workable.

In fact, humus helps to correct the defects of sand on the one hand and clay on the other. Let us see how it works in each case.

A coarse, sandy soil is undesirable for three main reasons. Firstly, it has very little capacity for retaining moisture. It soon dries up after rain and crops sown on it soon suffer from drought. Secondly, it is loose and unstable. The sand particles do not stick together and may be blown about by the wind when dry. This can be seen in sand-dunes along our coasts. Thirdly, it is very poor in plant food, and even if manures and fertilisers are given to it, they are soon washed out. Every farmer knows that sandy soils are hungry. Humus has a great capacity for retaining moisture so that when we increase the amount of humus in a sandy soil we increase its storage capacity for moisture and help to ensure against drought. It also acts as a kind of cement to stick the particles of the soil together, so that instead of being loose and liable to be blown about by the wind they become grouped into clusters or groups of particles which are sufficiently big to stay put in strong wind. Lastly, humus acts as a storehouse and regulator of plant food in the soil. When we increase the amount of humus we not only add to the supply of plant food but we also increase the capacity of the soil to retain plant food added in manures and fertilisers.

Now let us see how humus affects clay soils. A raw, heavy clay soil poor in humus is sticky and plastic when wet and sets into hard clods when dry. It is impermeable to water and lies wet after rain. By increasing the amount of humus we break up the clay so that the soil becomes more crumbly and friable. It does not paste so readily when wet and does not form such hard clods when dry. It is thus easier to work to a seed-bed, and as it is more open in structure it lets water drain through more easily.

The effect of humus can be well seen in old garden soils. Whether in a sand country or in a clay country, these soils, which have received heavy dressings of farmyard manures for many years, are always more fertile and manageable than adjoining soils that have not received such heavy dressings. The sand and clay characters are, in fact, much less strongly shown in the mature old garden soils.

Apart from the physical and chemical effects of humus, it is important as the home of the living population of the soil. In an ordinary soil there is a great variety of organisms. Earthworms can be readily seen, but there are many other lowly forms of animal life. Belonging to the plant kingdom are many kinds of fungi and bacteria, the latter present in enormous numbers—many millions in an ounce of soil. All these micro-organisms play their part in the decomposition of plant materials, straw, roots, etc., added to the soil. In this decomposition, plant food is set free for the nutrition of plants, and humus is formed, which becomes built up into the body of the soil.

The mode of action of these micro-organisms, and therefore of the

decomposition of plant materials added to the soil, is markedly affected by conditions in the soil. In a well-aerated soil with a sufficiency of lime, plant residues tend to be completely decomposed just as if they were burnt in air. The rate of decomposition depends on the temperature so that with high temperature, as in the tropics, and free aeration, plant residues quickly disappear from the soil. Other things being equal, decomposition is more rapid in sandy soils than in clay soils because of this better aeration.

In a soil with poor aeration, as under waterlogged conditions, the decomposition of plant residues takes a different course. The decomposition is no longer complete, as when abundant air is present. Most of the plant material remains in the soil in an altered form as humus. Humus is a dark-coloured substance in which all trace of the structure of the original plant material has disappeared. An extreme case of this kind of decomposition is seen in peat, which is formed under conditions of permanent wetness. Peat consists almost entirely of humus. Humus is formed even in well-drained soils because such soils are poorly aerated during part of the year, and apart from this there are compound particles or crumbs in the soil into which air does not penetrate. It is just as well that this is so, because if a soil were well-aerated throughout the year, and if every part of the soil were always well-aerated, plant material added to the soil from crop residues and farmyard manure would quickly waste away.

The amount of humus in the soil depends on the balance between additions of organic matter from crop residues, etc. and losses by decomposition. These losses are greatest in soils with excessive aeration like dry sands, and least in waterlogged soils. As in most cases, the desirable state of affairs is a mean between two extremes. Some break-down is necessary, because in this way plant food is made available for plants, but on the other hand the supply of humus must be maintained in order to keep the soil in a good physical condition.

Nitrogen cycle in soils.—The decomposition of organic matter by the living organisms of the soil has an important bearing on the supply of nitrogen to plants. Of all the elements of plant food, nitrogen is the most likely to be deficient. Judged by unit price, nitrogen is the most expensive of the manurial elements. Although most soils contain thousands of pounds per acre of nitrogen in humus, the greater part of it is unavailable to crops, so that 20 lb. or so of nitrogen per acre in the form of sulphate of ammonia often gives a big increase in yield. Now, the very conditions which favour the breakdown of plant materials in the soil, namely, warmth, good aeration, and a good lime status, also favour the liberation of soluble and available nitrogenous compounds from added organic matter and from the reserves in the soil. This process thus helps towards economy in the use of nitrogenous fertilisers.

Apart from the soil organisms that are concerned with the mobilisation

of available nitrogen for plants, there are other organisms that actually obtain nitrogen from the air and thereby increase the supply of nitrogen for the use of crops. Leguminous plants, e.g. beans, peas, vetches, and clovers, all serve to increase the nitrogen of the soil through the activity of certain bacteria formed in small swellings or nodules on their roots. It has been known for centuries that these crops have a favourable effect on soil fertility, but it was only towards the end of the last century that this effect was found to be due to the action of nitrogen-fixing bacteria. More recently, it has been found that there are other bacteria in the soil living on their own account which can also catch nitrogen from the air and thus increase the supply of nitrogen for the use of crops.

The importance of the nitrogen-fixing bacteria in the soil is obvious. Indeed, most of the nitrogen in the soil is ultimately traceable to their activity. Nitrogen in added fertilisers merely supplements these natural supplies of nitrogen.

GENERAL VIEW OF THE CONSTITUTION OF SOIL

We have now seen what are the main constituents of soil. How are they, so to speak, assembled together? The coarser mineral constituents, namely the stones, gravel, sand, and to a large extent the silt, form as it were the skeleton of the soil. The really active part of the soil is the clay, together with the humus. Clay and humus have an enormous capacity for absorbing water. When a soil is poor in clay and humus it can hold very little water, as may be seen in the coarse sand of dunes along our coasts. Clay and humus also act as a kind of cement, binding the clay particles of the soil together. A soil containing little clay and humus consists of a lot of loose particles which are easily blown about by the wind when dry. Of course, where too much clay is present the particles may stick together when dry to form hard clods as every farmer knows who has to do with a heavy clay soil in a dry spring. When there is much clay present a soil is apt to "paste" when wet.

The clay and humus together are important, above all, as storing up and regulating the supply of nutrients to plants. Clay and humus react with soluble fertilisers so that their plant food is held in the soil and not washed into the drainage. Indeed, if a soil contained no clay and humus it would probably be necessary to give a fresh dose of plant food as fertiliser after each heavy downpour of rain. Under ordinary farm conditions the greater part of the lime, phosphate, potash, nitrogen, etc. taken from the soil by each crop, is supplied from the stores held by the clay and humus. Of course, under intensive culture, particularly in glasshouses, most of the plant food is supplied from added fertilisers, but even here the clay and humus act as a regulator of the supply.

SOILS AS INDIVIDUALS

There is a very real distinction between soils as individuals and soil as a material. It is something like the distinction between a live animal and the bone, meat, and hide of which it is composed. Every farmer will probably claim that he has several different kinds of soil on his farm, and when we consider the soils of a whole country, the number of different kinds of soil is very great indeed. Farmers recognise different breeds of cattle, sheep, horses and pigs. Should not the different kinds of soil in our country be as clearly distinguished? Farmers do, in fact, distinguish different kinds of soil, but they generally think of the texture, i.e. whether a soil is a clay, a heavy loam, a medium loam, a light loam, or a sand, or more simply whether it is a heavy or a light soil. If texture were the only thing that mattered, it would be possible to distinguish soils on this basis, but what one farmer might call a loam another farmer might call a clay, depending on his own experience of soils. But apart from this, texture is not everything, even although it is very important. One clay soil differs from another clay, and there are considerable differences in loams. Let us, therefore, try to consider what characters are of most importance in distinguishing soils from each other.

First, there is the actual material from which the soil is formed. In some cases this is the solid rock underlying the soil, in other cases it is boulder clay, hill wash, or alluvium. Generally speaking, it bears some relation to the geology of the place. In a journey across the country, one can see how the soil changes with the geology as one goes from the hard rocks of Wales or the Lake District, across the Carboniferous limestone of the Pennine regions, the red Triassic rocks of the Midlands, and the soft limestones, clays, and sands of the newer formations in the south and east.

Secondly, and this depends in a large measure on the nature of the parent material of the soil, there is the texture. Here there is a great range from the heaviest clays to the lightest sands, and the variety is still greater if we take into account the varying amounts of stones present.

Thirdly, there is the proportion of humus in the soil. We can find all gradations from light blowing sands with little or no humus to peat soils consisting almost entirely of humus.

Fourthly, there is the depth. If we divide the soil profile roughly into soil, subsoil, and raw parent material, we see all possible variations, from the deepest to the shallowest soils. Generally, but not always, the deepest soils are found in the lowlands, but even there, particularly in heavy clays, the actual soil may be quite shallow if drainage is poor.

Fifthly, there is the drainage and here again we can distinguish all variations from extremely dry soils where the rainfall is quickly lost to soils that are permanently waterlogged. Excessive dryness or excessive wetness are both bad, and both may be seasonal or permanent.

Now all these characters of soils are more or less permanent or

inherent. The parent material and the texture are unalterable; the others can be altered only to a limited extent or by operations lying out of the range of ordinary management. For example, the humus content can be increased and the soil can be deepened, but only by long-term operations. Dryness can be remedied by irrigation and wetness by drainage, but these improvements will not alter the inherent nature of the soil.

Soil Maps.—The variety of soils, even in our small country, is almost infinite. This immense variety in soil results from the variety in the geology, the surface relief, the climate, and the drainage conditions in different regions. The kind of variations that occur will be seen from the descriptions of a few well-known kinds of soil. These soils have been recognised and mapped in the Soil Survey of England and Wales. For survey purposes soils are named after the locality where they were first recognised or where they commonly occur. A set of soils thus recognised is called a *series*. Thus the Penrhyn series is so called because it was first studied and recognised at Penrhyn, near Bangor. In order to show how soils can differ, we will now describe some typical series.

1. *Penrhyn series.*—These are soils derived from hard shales. They are rather stony and vary from light loams to rather heavy silty loams. They are of moderate depth and are naturally well-drained. They are found in western districts, mainly in North Wales and North-west England, and owing to the high rainfall and the prevalence of grassland husbandry, they are well supplied with humus. They tend to be deficient in lime. They are moderately fertile soils under permanent grass or alternate husbandry.

2. *Salop series.*—These are derived from Triassic boulder clay. They are generally medium to heavy loams overlying reddish clay subsoils. They are generally of moderate depth, but sometimes the raw clay is met with at shallow depths. The drainage is sluggish or impeded and artificial drainage is generally necessary. Mole drainage is often very effective on these soils. The lime status is moderate. With good management these are fairly fertile soils and more adapted for pasture than for arable. Much of the dairy country of Cheshire consists of Salop soils.

3. *Sherbourne series.*—These soils are formed from and overly the harder limestone of the Inferior Oolite. They may also occur over other similar limestones of the Jurassic system. They are bright rusty-brown, rather stony, heavy loams passing down through lighter-coloured heavy loam or clay loam to weathered and shattered limestone rock. They are generally rather shallow and the rock may occur at less than a foot, but deeper phases are found at the foot of slopes and in hollows. They are well-drained and tend to suffer in drought. They contain plenty of lime. Much of the dry soil of the Cotswolds belongs to the Sherbourne series.

4. *Charlton Bank series.*—These soils are derived from disturbed Lower Lias clay and occur on gentle slopes or low-lying areas. They are stoneless,

sticky, dark clays over yellowish mottled heavy clay, passing to blue-grey clay. Impeded drainage with extreme wetness is pronounced and renders arable use difficult. Lime status is high.

5. *Cheltenham series*.—These soils are derived from the Cheltenham sands and are deep dark-coloured sands over yellow or buff coarse sand. Lime status is high and drainage-free. The Cheltenham soils are very suitable for intensive arable use.

6. *Winchester series*.—Derived from clay-with-flints overlying chalk. Very stony (flinty) medium to heavy reddish loam over red stony clay, overlying chalk. The soil is variable in depth, but generally rather shallow. Lime status is moderate to low. The drainage is imperfect or impeded.

7. *Upton series*.—Derived from chalk. Shallow, greyish, chalky, light loam with abundant flints passing at shallow depth to flinty chalk rock. Drainage is excessive and these soils are very subject to drought.

The above examples represent only a selection from the very large number of distinct kinds of soil known to occur in this country. Within each of these soil series there are variations. The principal variations are in texture. Thus, in the Penrhyn series we find as textural types, a range from heavy silty loam to light loam. These would be described as Penrhyn heavy silty loam, Penrhyn medium loam, Penrhyn light loam, and so on. In practice, the range of texture within a series is limited, and we should not expect to have a Penrhyn clay or a Penrhyn sandy loam. On the other hand we may get variations due to the presence of stones or gravel, giving types such as Penrhyn stony loam, Penrhyn gravelly light loam, and so on. Finally, we can recognise phases depending on depth and steepness of slope. We might have for example, Penrhyn medium loam, shallow phase or Penrhyn medium loam shallow phase, and so on.

It will be instructive to take the seven series described above and see how they differ in their agricultural capabilities. If we indicate their suitability for arable, mixed, or grassland by A, B, and C respectively, where A indicates very suitable, B moderately suitable, and C unsuitable,[1] their capabilities may be set out as follows:

	Suitability for		
	Arable	*Mixed*	*Grassland*
Penrhyn	B	B	A–B
Salop	B	B	A
Sherbourne	B	B	C
Charlton Bank	C	C	B
Cheltenham	A	A–B	B
Winchester	B–C	B	B
Upton	B	B	C

[1] By "unsuitable" is meant that land thus used can be expected to be only of moderate productivity. Thus, the Sherbourne series is unsuitable for grassland to the extent that first-class grazing cannot be expected on it. Yet, it can and does find a use as semi-rough grazing for sheep.

BRITISH SOILS

The character of the soil depends on the material from which it has been formed, the situation and the climate under which it has developed, and on its history under human occupation. In a broad way, however, we can group the soils of our country according to the surface geology, i.e. according to the type of rock material from which they have been formed. The correspondence is not exact, because the same kind of parent rock material can give rise to different kinds of soils, according to the conditions of development. However, for the purpose of giving a short account of British soils, the geological map probably forms the most convenient starting-point.

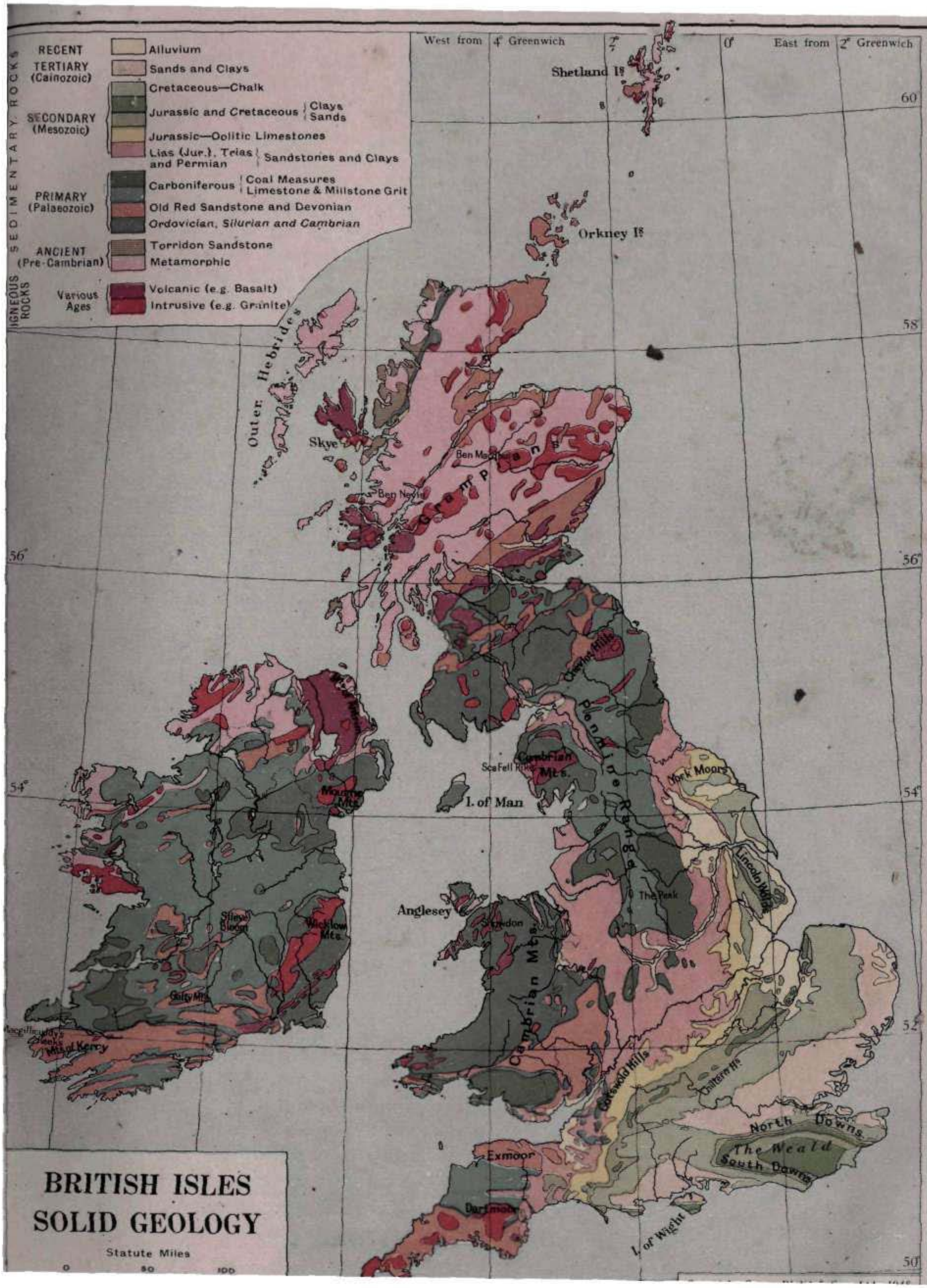
Owing to the geological structure of Britain, the harder and more ancient rocks tend to occur in the west and north, and the newer rocks to the south and east. The regions of ancient rocks are also generally the regions of highest rainfall. We thus have a marked contrast both in parent material and in climate.

The most ancient rocks, the so-called Pre-Cambrian, occur principally in the Scottish Highlands, but also in Anglesey, with smaller areas in Pembrokeshire, Shropshire, and Leicestershire. The glacial drift associated with these rocks in lowland areas gives generally light stony soils of moderate fertility, but there are also great areas in waste, often with considerable development of peat.

Rocks of the Cambrian, Ordovician, and Silurian systems occur over a large part of Wales, in the Lake District, and in the Lowlands of Scotland. Much of the land is mountainous. In the lowlands, the freely-drained soils often suffer through being shallow and stony, whilst the deeper soils are often affected by poor drainage. Typically, they are stony or shaly loams of moderate fertility. By reason of the generally wet climate they are more suited to grassland or alternate husbandry than to arable. Lime is usually deficient, and regular dressings of lime are necessary to maintain productivity.

The soils, mainly red loams, associated with the Devonian and Old Red sandstone, in Devon, South Wales, Hereford, Shropshire, and parts of Scotland, are generally more fertile than those already mentioned. This is partly connected with the more favourable conditions of situation and climate, but is also due in a large measure to their inherent characters. Even under the same climate, it is often possible to note the improvement in the appearance of the country in passing from the older formations to the Old Red sandstone. This may be seen in South Wales, Anglesey, and perhaps most markedly in Scotland.

The soils of the Carboniferous system form a wide range. Those associated with the Carboniferous limestone, e.g. in the Peak District of Derbyshire, are generally thin, dry, upland soils in rough grazing, but with occasional stretches of good light loams in the valleys. Millstone Grit soils are generally poor and deficient in lime, as may be seen in much of the


BRITISH ISLES
SOLID GEOLOGY
Statute Miles
0 50 100
SEDIMENTARY ROCKS
RECENT
Alluvium
TERTIARY (Cainozoic)
Sands and Clays
SECONDARY (Mesozoic)
Cretaceous—Chalk
Jurassic and Cretaceous {Clays / Sands}
Jurassic—Oolitic Limestones
Lias (Jur.), Trias and Permian {Sandstones and Clays}
PRIMARY (Palaeozoic)
Carboniferous {Coal Measures / Limestone & Millstone Grit}
Old Red Sandstone and Devonian
Ordovician, Silurian and Cambrian
ANCIENT (Pre-Cambrian)
Torridon Sandstone
Metamorphic
IGNEOUS ROCKS
Various Ages
Volcanic (e.g. Basalt)
Intrusive (e.g. Granite)
West from 4° Greenwich
2°
0°
East from 2° Greenwich
60
58
56°
54°
52
50
Shetland Is
Orkney Is
Outer Hebrides
Skye
Ben Macdhui
Ben Nevis
Grampians
Cheviot Hills
Pennine Range
Cambrian Mts.
Sca Fell Pike
York Moors
I. of Man
Mourne Mts.
Lincoln Wolds
The Peak
Anglesey
Snowdon
Wicklow Mts.
Slieve Bloom
Galty Mts
Macgillicuddy's Reeks
Mts of Kerry
Cambrian Mts.
Cotswold Hills
Chiltern Hs
North Downs
The Weald
South Downs
Exmoor
Dartmoor
I. of Wight

poor soil in the West Riding of Yorkshire. The Coal Measures, where not occupied by mining and industry, give two types of soil, one a rather light loam of moderate fertility and the other a heavy loam, usually showing poor drainage, and difficult under arable cultivation. Locally, as in parts of North Wales and Shropshire, certain red rocks of the Coal Measures give very fertile red loams. The narrow outcrop of Permian rocks running from Durham through Yorkshire, roughly along the line of the Great North Road and down into Nottinghamshire, gives sandy loams, and also, over the Magnesian Limestone, soils similar to those derived from the Carboniferous Limestone.

The Triassic formation occupies a considerable area of the Midlands and runs up into Yorkshire on the east and into Lancashire on the west of the backbone of England. There is also an extension down into Devonshire, as well as isolated areas in Cumberland. The lighter soils of the Trias, derived from the Bunter and Keuper sandstone and their associated drifts, are generally light sandy loams, locally so light that in some places they form barren heaths, as in Cannock Chase in Staffordshire. Generally they form first-class arable soils, and some of our best farmed land, e.g. in Shropshire and the Ormskirk district of Lancashire, is in this class; but it should be noted that their productivity is mainly the result of high farming. Under poor management, they soon degenerate. The heavier soils of the Trias are derived from the Keuper Marls. Most of the good dairy land of Cheshire lies on boulder clay of Keuper Marl material. Although well-suited to carry high-class pasture, they are also well adapted to mixed farming or alternate husbandry.

The Jurassic system of rocks extends across England from North Yorkshire through Lincolnshire and the Midlands to Dorset. It includes a great variety of rocks and a corresponding variety of soils. The Lias or lower Jurassic gives rise mainly to heavy grey clay soils, occuring typically in Leicestershire, South Warwickshire, and the Vale of Evesham in Worcestershire, but lighter soils occur locally, as near Banbury. The clay soils, formerly wheat and bean land, were mainly in pasture at the beginning of the recent war. Some of the high-grade pastures of Leicestershire are derived from Lias material. In the Vale of Evesham, in spite of their heavy texture, they are used successfully for market gardening and fruit growing. Their high lime status is a favourable factor.

The soils of the Upper Jurassic fall mainly into two groups, namely the clays and the limestone soils. The clays derived from the Oxford and Kimmeridge clays are generally wet and intractable under arable. Naturally, they are almost entirely in grassland, not always of the best quality, but susceptible of improvement. The thin dry soils of the Cotswolds are typical of the Jurassic limestone soils.

The Cretaceous system includes the Wealden and Gault clays, with soils similar in many respects to the Kimmeridge and Oxford clays. There

are also sandy soils derived from the Greensand. In this group are the soils of the Biggleswade and Potton district of Bedfordshire. The greater part of the Cretaceous is occupied by the Chalk, which runs down from East Yorkshire through Lincolnshire, East Anglia, and the Chilterns to Salisbury Plain and sweeps round to form the North and South Downs. The soils are thin and droughty on the higher ground, but become deeper in the valleys. These soils are predominantly arable. The former practice of sheep folding on them has largely fallen into disuse but still has its advocates. The thinner soils of the uplands form dry sheep pastures.

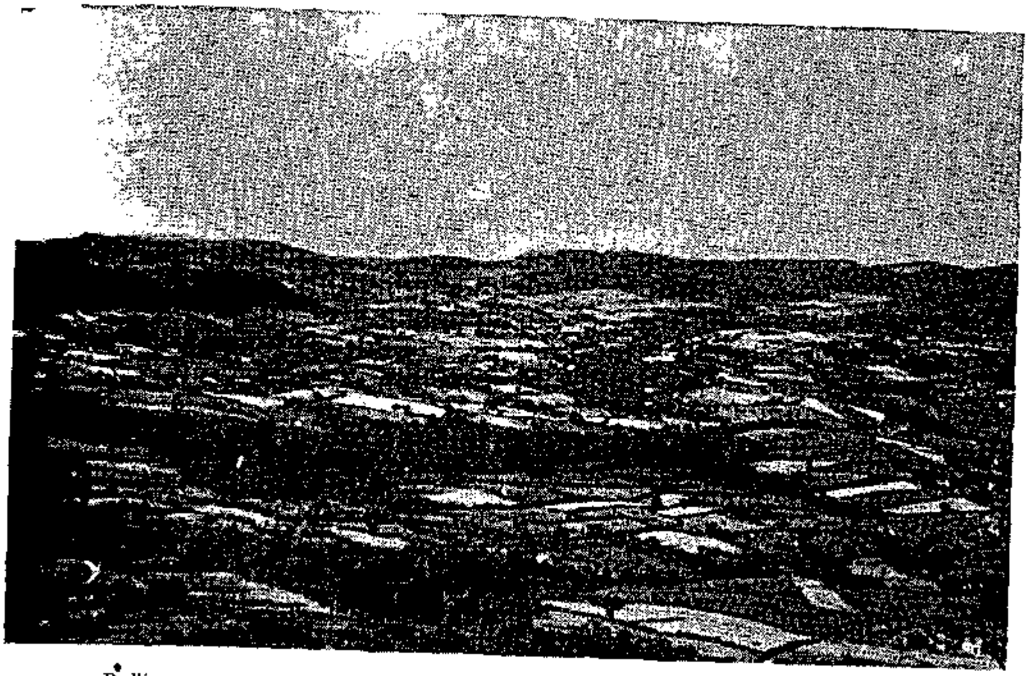
Tertiary deposits are found in the London Basin, extending as far as Reading to the west, and up into East Suffolk and East Norfolk to the north. They are also found in the Hampshire Basin. They give a great variety of soils, ranging from the heavy clay loams derived from London Clay, to the light soils, often in heathland, of the Bagshot beds.

Soils from recent deposits include the fertile brickearths, the poor stony clays of the clay-with-flints, the hungry stony soils of the Plateau and Valley Gravels, the peat soils of the Fens, and the alluvial silts of the Spalding district, probably the most highly-farmed soil in Britain. We may also class with this group of soils the reclaimed coastal marshes, such as the famous Romney Marsh in Kent.

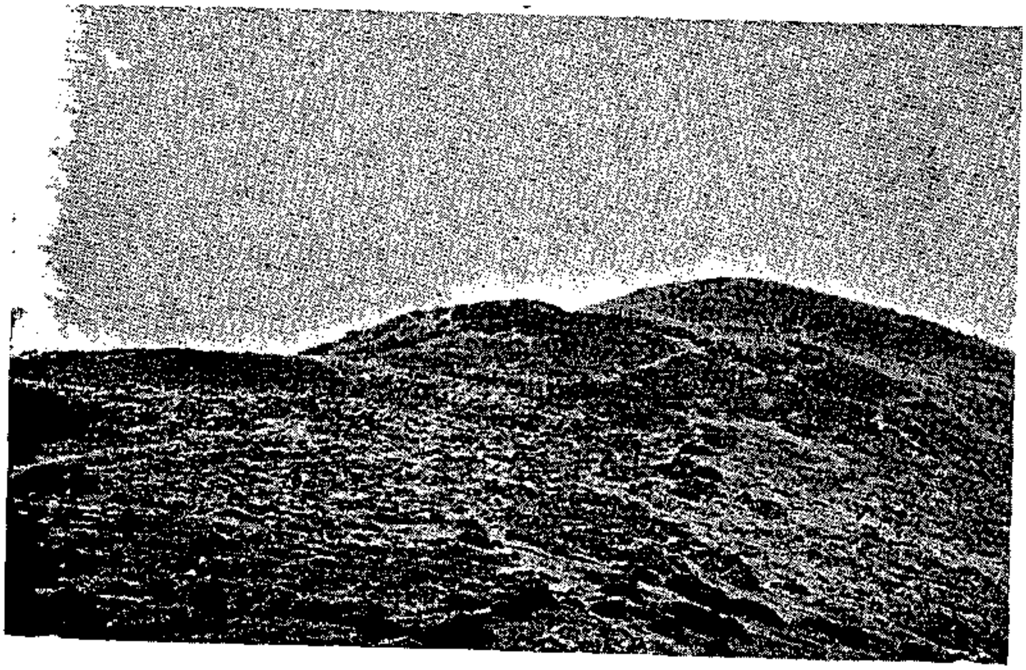
PHYSICAL PROPERTIES OF SOILS

When we speak of the physical properties of a substance such as iron, wood, or copper, we mean such things as its density, its relationships to heat, its electrical conductivity, its elasticity, and so on. We mean its properties as a material. In the case of the soil, its physical properties are those characters that affect its behaviour under tillage, the supply of moisture and air within the soil, the disposal of rain falling on the soil, and the response of the soil to changes in air temperature and sunshine. All these properties depend on the proportion of the different constituents present in the soil, the way in which they are built up, and the way in which the different strata or horizons of the soil and subsoil are arranged. The physical properties of the soil are of the greatest importance as controlling soil fertility and the response of the soil to the labours of the farmer.

Soil Structure.—We have already discussed soil texture and we have seen that soil may be considered as being built up as a skeleton or framework of the coarser particles, clothed and knit together by the more active clay and humus. The way in which the particles of soil are built up is termed the *structure*. The structure of the soil corresponds approximately with what the farmer calls tilth. Now, although a given soil has a constant texture, i.e. the same relative proportions of gravel, sand, clay, and humus, its structure can change. We can make this plain by means of a simple experiment. If we take a pint pot and fill it loosely with dry soil, we should find that we could add possibly half a pint of water to it before the pot



Rolling country near Conway. The higher ground is in rough pasture or woodland.
(*By courtesy of R. E. Hughes.*)



Thin mountain soil over hard rock.
(*By courtesy of R. E. Hughes.*)

would overflow. The water would fill into the spaces between the lumps and crumbs of the soil. This space is called *pore space* and in an ordinary soil amounts to about 50 per cent. of the total space occupied by the soil. Now, if we were to take our soil and fill it into the pint pot, bit by bit, stamping it down hard after each addition, we might find that we could get only one quarter of a pint of water into the pot without overflowing. By packing the soil tight we should have reduced the pore space. In a freshly ploughed soil the pore space is at its greatest. As the soil is worked down to a seed-bed the pore space will decrease a bit and settle down still farther during the season, until it reaches its lowest figure after harvest. Other things being equal, soils with good proportions of clay and humus have greater pore space than coarse sandy soils. This is because clay and humus have the effect of sticking the particles of the soil together into compound aggregates or crumbs. In a coarse sand, low in clay and humus, the particles behave independently of each other and can pack more closely.

The pore space of the soil can be filled with water or air. In a completely dry soil the pore space is all air, whilst in a waterlogged soil it is all water. Neither of these are desirable states, because in the one case the crop roots are deprived of water and in the other of air. For healthy growth the crop needs as much moisture as it can get, provided there is also enough air in the soil for the roots to breathe and to maintain the soil itself in a healthy condition. Is a high pore space, say 50 per cent. or more, a good thing or a bad thing? Generally speaking, a good thing, particularly if some of the space consists of openings between the crumbs through which water and air can pass easily. Actually, it is not so much the total pore space that matters as the proportion of these wider spaces in the soil that help aeration and allow water to percolate freely. A sandy soil may have a pore space of only 35 per cent. but will be well-aerated because most of this is in wide spaces. The fine spaces within the crumbs can be filled with moisture, whilst the wider spaces between the crumbs can be mainly filled with air, and this is generally a desirable state of affairs. On the other hand, too loose a structure, particularly when the soil is bare, may result in excessive loss of moisture from the immediate surface. When this occurs, consolidation with a roller, by pressing the dry soil on to the moister soil below, will enable the surface soil to absorb the necessary moisture for the use of a sown crop.

Soil Moisture.—The importance of suitable moisture conditions in the soil is obvious. Indeed a large proportion of the farmer's grumbles are about either too much or too little moisture in the soil, and whilst excessive wetness on the one hand and excessive dryness on the other are mainly governed by the weather, it is quite evident that soils differ greatly in the way in which they behave under heavy rainfall or drought. Even in very wet weather some soils never get waterlogged and unmanageable, and on the other hand are not much affected by drought. What does the farmer ask of the soil in this respect? First of all, he wants his soil to hold moisture

sufficiently well to supply the needs of his crops during periods when no rain falls. Secondly, he wants his soil to be able to dispose of excess moisture easily so that it does not become waterlogged, and to dry up quickly enough after rain for him to be able to carry out any cultivations required, particularly in the spring months.

Soils differ considerably in their capacity for retaining moisture. At the one extreme, we have coarse sands which hold very little moisture and dry up quickly when rain ceases; at the other extreme are peats which hold an enormous quantity of moisture. The capacity of a soil for holding moisture depends on its content of clay and humus. Now it is not an easy matter to increase the amount of clay in a soil, but the stock of humus can be built up by good dressings of farmyard manure, by green manuring, and by establishing strong grass leys. In this way the natural deficiency of a sandy soil can be to a considerable extent overcome.

So much for the retention of moisture by the soil. Its ability to get rid of excess moisture depends upon its texture and structure. A sandy soil is naturally open and quickly allows excess moisture to drain away. A heavy clay soil, particularly if it is poor in humus, tends to be impervious to the movement of water, so that excess moisture drains away very slowly. However, if the structure or tilth of the soil can be improved by increasing the amount of humus and by skilful cultivation, even a clay soil can become opened up so that excess moisture will drain away.

As we have already seen, a soil does not consist only of the immediate top-soil, and when considering the moisture conditions of the soil we must take into account what lies below. We must think of the whole soil profile. When we dig down into the soil we generally find that the lower layers are moister than those at the surface. In a low-lying situation we shall often find that not far from the surface the subsoil is completely saturated, so that a hole will fill with water up to a few feet from the top. The level of this ground water is called *water-table.* The water-table comes near the surface in the bottoms of valleys, but may be far below the surface in uplands. The surface of the water in a well marks the level of the water-table. An impervious stratum of clay or rock may bring the water-table near the surface in upland situations.

Now the presence of a water-table near the surface has an important effect on moisture conditions at the surface. Even with a light sandy soil, if the water-table is at the surface, the soil will be waterlogged. If by suitable drainage the water-table can be lowered to three or four feet, moisture conditions will be very favourable because the open character of the soil will allow excess moisture to drain away, whilst the presence of water at a moderate depth will ensure that crops growing on the soil will not suffer from drought because their roots can reach the moisture in the layers of the soil above the water-table.

The position of the water-table will vary between summer and winter. Any rainfall in excess of that held by the soil sinks down to the water-table.

In winter, when there is very little evaporation from the soil and little moisture used by crops, most of the rainfall percolates down to the water-table, which will, therefore, stand higher. There is also an increased flow into the ditches from any drains leading into them. In the summer there is more evaporation from the soil and a considerable amount of moisture is used up by growing crops. There will thus be less moisture draining down into the subsoil, and the level of water in the ditches will fall.

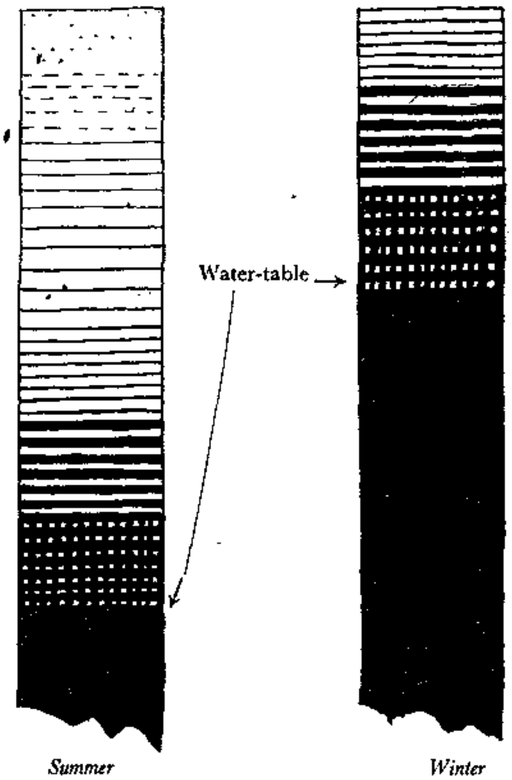


Fig. 1.—Moisture conditions in light soil with fluctuating water-table

It is interesting to compare the behaviour of moisture in the soil under some different conditions. Let us consider first the case of a sandy soil in a low-lying situation. Fig. 1 shows diagrammatically the state of affairs in the summer and winter respectively. The wetness of the soil is indicated by the darkness of the shading. Black shading thus indicates complete saturation at and below the water-table. In the summer the water-table is low and there is a gradual fall in the amount of moisture as we go to the surface, which may be almost completely dry. In winter, with a high water-table the surface remains wet.

Now consider the case of a soil with a heavy clay subsoil. Here it is usual to find that, even in winter when the soil is waterlogged, the deep

subsoil is quite dry. The water-table is, so to speak, "perched" on the clay subsoil. In winter the soil is wet to the surface, but in summer it may dry out so that crops may actually suffer from drought. This state of affairs is shown in Fig. 2.

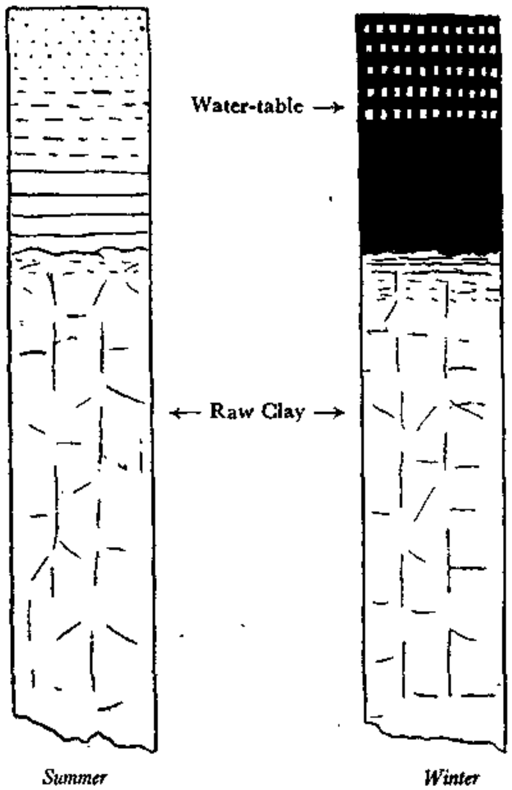


Fig. 2.—Moisture conditions in heavy soil over impervious clay subsoil

In the case of freely-drained soils in upland situations, e.g. many of the chalk soils of S.E. England, the water-table may lie at a great depth below the surface. The moisture situation in summer and winter, respectively, can be represented diagrammatically by Fig. 3. In summer there is an increase in the moisture status going from the soil to the subsoil. In drought the depth to which drying may occur increases. In winter the whole profile is moister and after heavy rain the surface layers may be waterlogged. But this excess of moisture soon sinks in the soil, moistening the layers below. If rain is long continued, water is eventually passed down to the deep water-table. After a dry summer it may be months before this occurs. Penetration of rainfall is easier in arable than in grassland. Where there is a heavy matted turf, it is quite usual to find the soil dry at the end of October or even later.

The moisture conditions in the soil are an important, perhaps the most

important, factor in determining the general fertility of soils. The great majority of infertile soils, including most waste and uncultivated soils, suffer either permanently, or temporarily, from too much or too little moisture. The thin soils of our mountainous regions, even although they occur under high rainfall, are very liable to drought during summer, and this is, in itself, a major obstacle to their improvement.

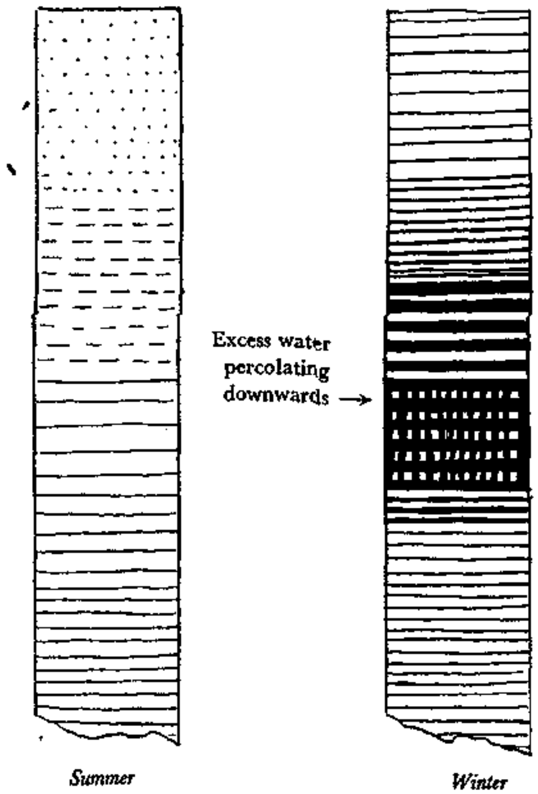


Fig. 3.—Moisture conditions in freely drained soil with deep water-table

A fertile soil should be able to supply sufficient moisture to growing crops during the intervals between rain. One of the best safeguards against drought is a good depth of soil. This enables the development of a deep root system so that, even although the surface soil may dry out, there is still abundant moisture available below. On the other hand, a shallow rooting system, such as results from bad drainage, restricts the amount of moisture within the range of the root system. Drainage, by deepening the layer of aerated soil, promotes root development and, therefore, ensures against drought.

In light soils it is often an advantage to have a water-table within a few feet of the surface. This means that the roots of crops can draw on the moisture in the zone above the water-table. Where the water-table

can be maintained artificially at a constant depth of, say, about 5 feet, moisture conditions are very favourable for intensive culture such as market gardening. This is possible in many low-lying sandy areas near our coasts.

Drainage.—It is not possible within the compass of the present article to deal with the actual technique of drainage. We will, therefore, merely discuss the principles underlying drainage. The object of drainage is to facilitate the removal of superfluous water from the soil profile. The problem and the methods of dealing with it will differ and the following cases may be distinguished.

(1) The soil may be wet because the regional water-table is at or near the surface. This is the case in many alluvial soils and in unreclaimed fens and peat bogs. Such lands are often subject to seasonal flooding. Since land of this type lies at or near the level of the local river system, it is often necessary to use pumping in order to lower the water-table. Embanking of rivers may be necessary. Drainage of this type generally involves considerable areas and requires carrying out on an arterial basis as in much of Holland and in the Fen district of England. The area to be drained is cut up by a system of ditches leading into main ditches from which the water is pumped over an embankment into a main river or estuary. In some cases sufficient removal can be effected by means of outfalls working at low tide but closed at high tide. Pipe drainage may be necessary to drain the fields between the open ditches.

(2) The wetness may be due to the impervious character of the subsoil. This is the case in much of the clay country of Britain. As these areas are often low-lying, arterial drainage may also be necessary. The problem is essentially that of a local water-table overlying a clay subsoil. The treatment consists in laying a grid of tile drains opening out into a ditch on the lower side of each field. For success, it is necessary to have as deep a layer as possible of permeable soil over the clay and for the filling above each line of tiles to be permeable. The superfluous water then percolates down to the surface of the clay and over this towards the trench in which the tiles are laid. If tiles have been laid very deep and the filling of the trench has become completely consolidated so as to be impermeable, the excess water can no longer sink down and the tiles may remain completely dry even although the surface is waterlogged. A drainage system can also become useless if the ditches become filled in above the level of the outfalls. In many cases, the cleaning out of ditches and the repair of outfalls can cause tile drainage systems to function again.

Mole draining, in some cases, may be a cheap substitute for tile draining. It may be used where the subsoil is a stoneless clay and on land with sufficient slope. It is not likely to be effective on flat land, or where the subsoil has not sufficient "body" for the mole channels to persist. It cannot be used where the subsoil contains many stones or boulders. As in the case of tile drains, the efficiency of mole drains depends to a large extent

on the permeability above the actual channels. If the groove made by the mole becomes completely closed, water can no longer percolate down to the mole channel.

(3) Wetness may be due to water seeping down from higher ground or coming out in springs. In the first, the water must be intercepted by a ditch. In the second case, the springs must be tapped and the water conducted in tiles or ditches to a stream or river.

Although a considerable amount of drainage has been carried out during recent years, very large areas still suffer from wetness. Many of these areas were once efficiently drained by tiles and ditches, but have gone back through neglect during the years of depression. Much could be done simply by attention to and the cleaning of ditches. But there are also considerable areas where the original tile system has ceased to function. Many low-lying areas require the institution of comprehensive arterial drainage schemes. Drainage can often work a spectacular change, for many badly-drained soils are of high potential fertility. As in other schemes of land improvement, however, the cost of maintenance must be borne in mind as well as the initial cost of the work.

Tillage Properties of Soils.—The principal object of cultivation is to obtain a seed-bed for the crop to be sown or planted, whether corn, roots, potatoes or grass. Cultivation aims also at the suppression of weeds. About these two objects of tillage there can be no doubt. When we come to the other aims or supposed aims of tillage, we enter the realm of controversy. It is generally considered that cultivation helps to aerate the soil and this is undoubtedly true to a certain extent. The breaking up of an old mat when a hide-bound pasture is ploughed certainly leads to healthier conditions in the soil. But some would go further and say that deep ploughing is desirable, because it increases the root range of plants and promotes aeration in the deeper layers of the soil and also facilitates the percolation of excess moisture. Against this view may be set the results of very careful experiments in southern and eastern England and in the United States where no advantage could be found for deep ploughing and subsoil cultivation. The truth is probably that the value of deep cultivation depends on the local conditions of soil and climate. It may be that for every combination of soil and climate there is an optimum depth, below which it will not pay to cultivate. If this is so, it is possible that in some districts farmers have not been ploughing deeply enough, and that a judicious increase in depth of cultivation would be profitable and may now be possible with the help of the tractor. More experiments are needed. Changes from proved practices should not be introduced simply because they appear to be desirable from a theoretical standpoint.

An important consideration in deciding the suitability of a given soil for arable cultivation is its actual behaviour under tillage. Every farmer knows that heavy soils are more difficult to work than light soils. In what does this difference consist? The behaviour of heavy clay soils can be

well illustrated by some very simple experiments. Take a small handful of wet clay and knead it in the hands. It will behave like putty and can be moulded into any desired shape. The mixture of clay and water is said to be *plastic*. Now try the effect of adding more water to the clay paste. Soon it will be noticed that the paste becomes more "slack" and a point is reached when it begins to stick to the hands. By working it with still more water it eventually gets to the consistency of a slow-pouring liquid like treacle. One can tell when it is no longer plastic but fluid, by putting some of it in the bottom of a basin and drawing a V-shaped furrow in it. If the paste is fluid the furrow slowly fills up.

We have seen that as the clay paste becomes wetter it ceases to be plastic and becomes fluid. What is the effect of drying the paste? Well, if we make it drier, either by mixing in some dry clay or by letting it gradually dry and kneading it from time to time, we shall find that the paste gets stiffer until we get to a point when on trying to mould it in our hands, it just crumbles down. There is, so to speak, a dry limit and a wet limit to plasticity. For instance, a heavy clay examined by the writer was found to be just plastic when it contained 30 per cent. of moisture. Below 30 per cent. it simply crumbled down. On the other hand, when it contained more than 50 per cent. of moisture it was no longer plastic, but fluid.

It is fairly obvious that it would not be sensible to cultivate a soil when it is plastic, as the effect would be to "paste" it. On the other hand, if the amount of moisture in the soil is just below that required to make it plastic, cultivation would have the effect of crumbling it down.

Now let us look at another property of clay soils, namely, *cohesion*. If a clay soil has been roughly ploughed and it dries out quickly it sets to hard clods, and the drier the clods get, the harder are they to break down by tillage implements. Very heavy clay soils when quite dry may set so hard as to be quite unworkable. When this happens one can only wait for rain, as after being moistened they loosen up and can be worked.

From what has been said, we see that clay soils are difficult because when they are too wet they paste and when they are too dry they are too cohesive. In very heavy soils, the margin between being too wet and being too dry is rather a narrow one, and that is why the clay farmer has got to be very skilful in seizing his opportunity for cultivation. With lighter soils, the margin is wider, and sandy soils, indeed, can be worked over a good range of moisture conditions.

The above considerations refer mainly to cultivations aiming at obtaining a seed-bed quickly. Where the object is simply to turn the soil over and expose it to the weather, as in autumn ploughing, one need not be so particular about pasting the soil as long as it is not too wet and sticky. Winter frosts have a wonderful effect in loosening the soil and rendering it easier to work down to a seed-bed with the spring cultivations.

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Many of the difficulties of clay soils have been lightened by the advent of the tractor. At the end of the summer, clay soils that would be too heavy a job for any ordinary team of horses, are readily ripped open by the tractor plough. Even so, clay soils are always difficult to handle and every effort should be made to counter their worst characteristics. Attention to drainage will help by facilitating the early stages of drying out in the spring. The use of liberal dressings of farmyard manure, if available, helps to render clay soil easier to work. Above all, the practice of alternate husbandry may be recommended. After a clay soil has rested in ley for a few years and acquired a good turf, it works down much more easily to a tilth. This was seen during the war years when many old clay pastures were brought under the plough and proved much less difficult to handle than might have been expected. Finally, clay soils are improved in their behaviour under tillage by the presence of an adequate supply of lime. Lime deficiency tends to make clay soils more difficult to work.

Soil Temperature.—The temperature of the soil is controlled mainly by the climate under which it occurs. Thus, in our British climate the surface soil attains a temperature of somewhere about 60° F. in the summer and falls to 40° F. or less in the winter with occasional periods of frost. Soil temperatures in summer are generally higher in the south-east than elsewhere. There is also the effect of altitude. In mountainous areas both summers and winters are markedly colder. Apart from these variations, there are local variations depending on slope, aspect, and general surface relief. A south slope is always warmer than a north slope. A low-lying area tends to be hotter than adjoining slopes in summer but can become a "frost pocket" at other times of the year, as some fruit growers and market gardeners know to their cost.

One of the most important factors affecting the temperature of the soil is its moisture content. In spring, the sun's heat has to warm up the moisture as well as the soil itself, and therefore a wet soil warms up more slowly than a dry soil. Every farmer knows that sandy soils are warmer than clay soils and this is mainly because they are drier.

Although soil temperature is governed mainly by the regional climate, and the various factors that we have mentioned, namely, altitude, slope, aspect, relief, and moisture content may make only a few degrees difference in the actual soil temperature, these differences may be very important as affecting earliness in the growth of market-garden crops. They also affect the length of the grazing season on grassland.

SOIL FERTILITY

Everyone knows that there are great differences in the value of land. Some land will sell for £100 or more per acre, e.g. good dairy land, orchards, or market gardens. At the other extreme we have upland grazings worth only a few pounds per acre. What are the reasons for

these great differences? Of course, it will be said at once that the soil of the orchard or market garden is better than the soil of the hill grazing. This is quite true, but the answer is not so simple as it appears at first sight, because the value of the land depends not only on the actual soil itself but also on the local climate, and on the kind of situation in which it occurs. Over and above these factors of soil and site, economic factors such as nearness to markets, labour supply, etc., may and often do play an important part in determining the value of land as judged by rental.

Realising that we have to consider not only the soil itself, but also the climate and situation in which it occurs, do we mean by a fertile soil a soil that will give heavy crops? At first sight this might appear a satisfactory definition, but it does not take into account the fact that the actual yielding capacity of a given soil depends in a considerable measure on the treatment it receives. With sufficient expenditure on cultivation and manuring, almost any soil can be made to yield big crops. It would seem, therefore, that what is really understood by a fertile soil is one that gives a good return for ordinary management. But we must distinguish further, because we must take into account the type of culture for which the soil is suited. One soil may give good returns under intensive horticultural utilisation, but would be only of medium productivity under mixed farming, and would be quite unsuited for grassland husbandry. Assuming, then, that the type of husbandry is suited to the soil, situation, and climate, we should judge the fertility of the soil by the return it gives for skilful management, always assuming that the type of utilisation, whether arable, mixed, grazing, or market gardening, is adapted to the actual conditions.

Let us look at some typical cases. First we will consider high-class grazing land. Here the expenditure in labour, manures, etc., is inconsiderable. The gross returns may be perhaps £10 to £15 per acre in live weight increase of grazing stock. Secondly we will take the case of good arable land. The expenditure on labour, manures, etc. is considerable and may amount to perhaps £15 to £30 per acre, but the gross return in saleable crops may be £25 to £50 per acre. Thirdly, in the case of market-garden land, the expenditure on labour, manures, etc. may be £50 or more per acre and the gross returns over £100 per acre.

Now each of the three soils would be considered highly fertile, but the gross profit per acre is least in the case of the rich pasture and greatest in the case of the market-garden soil. Against the greater gross profit on the arable and the still greater profit on the market-garden soil must be set the greater risks owing to weather, economic conditions, etc. The value of land to the cultivator depends to a large extent, but not entirely, on this margin between expenditure and gross return. Other factors are ruling price levels, wage rates, accessibility to markets, etc. It must be borne in mind also that the value of a given soil will depend on its being used efficiently for the type of husbandry for which it is best fitted. Thus it would be inexpedient to practise market gardening on a soil suited for

grazing or to attempt to maintain a market-garden soil as grazing land. Another point to notice is that in the examples given above, the part played by management, although important, is least in the case of the grazing soil and greatest in the market-garden soil. Without management the inherent productivity would probably be least in the market-garden soil, which might be poor rough grass or heathland in its unimproved state.

Although economic factors, such as accessibility to markets, labour supply, etc. are very important, for our purpose we will consider only the *physical* factors affecting the value of soils; these factors always operate whatever the economic conditions may be, and determine what can and what cannot be done with the soil. The physical factors, then, are *climate, situation*, and *soil*. Climate, modified by situation, above all dictates the general type of agriculture and choice of crops. It is because of our climate that we find in our Agricultural Returns such crops as barley, oats, potatoes, and not such crops as maize, sugar cane, and rice. Apart from the direct effect of climate and situation on plant growth, both act indirectly because they affect the character of the soil itself.

Effect of Climate.—The main factors in climate are temperature and rainfall. Dealing with temperature first, we know that, taking the average of the whole year, it is colder in the North of England than in the South of England. This means that, by and large, the farther north we go, the shorter is the growing season. Apart from the effect of latitude, altitude also affects temperature. This can be seen very well in N. Wales. Near the coast, in the beginning of April, trees and hedges will be coming into leaf and grass will be starting into growth, whilst in the interior uplands, the trees, hedges and fields still wear their winter aspect. Generally speaking, along our western coasts the winters are mild and the summers cool, whilst in the south and east, nearer to the continent, the winters are cold and the summers hot.

Variations in rainfall are even greater than those in temperature. At the one extreme we have the mountainous districts of Wales, the Lake District, and Scotland where the annual rainfall runs up to 100 inches or more. The wettest place in Britain is probably Llyn Llydaw under the peak of Snowdon with a mean annual rainfall of about 200 inches. Similar rainfalls are found in parts of the Lake District and in the Scottish Grampians. The lowest rainfalls are found in some eastern coastal districts, where the mean rainfall is well below 20 inches. Over most of England the mean annual rainfall varies from 25 to 30 inches. Closely connected with rainfall is atmospheric humidity. In wet districts, the air is generally moister than in dry districts. This means that the soil does not dry out so quickly in spring and it also affects the making of hay and the harvesting of grain crops.

As a general rule, sunshine varies inversely with rainfall. The drier districts are sunnier than the wetter districts. The south-west is rather sunnier than districts farther north having the same rainfall.

Wind may be an adverse factor in coastal districts and hilly or mountainous areas. Against this may be set the possibility offered by such situations of raising seed potato and other stocks free from virus infestation.

From what has been said, it can be seen that the climatic variations in Great Britain are considerable. Just as there are many types of soil, so there are many types of climate. The greatest contrast is between the wet climate of the west with its mild winters and cool summers and the dry climate of the east with severe winters and hot summers. The former is naturally suited for grassland and the latter for arable culture. Certain of the drier parts of the west are ideal for market gardening on account of the mild winter and the long growing season. (*See* chapter 4).

Effect of Situation.—When we speak of situation we mean height above sea-level, slope, aspect, and surface relief. All these have an effect on climate and also on the soil. First as to elevation, we may take it that there is a fall of 1° F. for every 300 feet increase in altitude. This means that the season is later and the growing season shorter in uplands than in lowlands. In mountainous regions, the spring is very late and the growing season very short. There is also a general tendency for uplands to be wetter than lowlands. The wettest areas of our country are in the mountains of Wales, the Lake District, and Scotland.

Aspect also modifies the climate. A south slope gets more sun and is, therefore, warmer than a north slope, an important point for market gardening. Slope affects the disposal of rainfall and steep slopes are usually dry. This is accentuated by the fact that soil is generally shallow on such slopes.

Surface relief acts mainly by its effect on depth of soil and on water conditions. Soil tends to accumulate in hollows and bottoms, which are generally moister than more elevated sites, and may even suffer from excessive wetness. Flats in the bottoms of valleys are often badly drained and liable to flooding. They are also liable to early and late frosts.

Finally, situation affects exposure to wind. High ground and coastal areas are generally wind-swept. In this connexion the relation of the general slope to the prevailing winds may be very important. Exposure to wind may rule out many upland areas for economic planting of forest trees. It may be desirable, however, to plant belts of trees to provide shelter for grazing animals even although they may not provide an economic return in timber.

Soil Characters Affecting Fertility.—What characters of the soil itself affect its fertility? To answer this question, we must understand what services the growing plant asks from the soil, and this necessitates a short discussion on the factors affecting plant growth

Most of the material of which plants are composed is built up from the carbon dioxide which is present in the air in the proportion of about 3 parts in 10,000. This remarkable process is carried out by the green

leaves of plants under the influence of sunlight. The sunlight supplies the energy, carbon dioxide and water are the raw materials, and chlorophyll, the green colouring-matter of leaves, acts as the intermediary in this process, known as *photosynthesis*. In photosynthesis, plant material is built up and oxygen is set free by the leaves.

Side by side with photosynthesis, there is the process of respiration, which is, in a sense, the opposite process because organic matter reacts with the oxygen of the air, producing carbon dioxide and water. Respiration is a property of all living matter. Just as human beings and animals require oxygen for breathing, so do plants, and this means that the roots of plants if they are to exercise their functions must have oxygen. In other words, the soil must be sufficiently well-aerated for the roots to "breathe."

Although most of the material of plants comes from the carbon dioxide in the air, plants also require certain elements from the soil. These elements which we term *plant nutrients* or *plant food* include nitrogen, phosphorus, sulphur, calcium, magnesium, potassium, iron, boron, zinc, copper, manganese, iodine, and possibly other elements. When we add manures or fertilisers to the soil, we are making good the deficiencies in plant nutrients. Plants are continually absorbing moisture from the soil and evaporating it off from their leaves. For every one part of dry plant material formed, from 200 to 1,000 parts of water are required. The nutrients pass into the plant mainly in this stream of water absorbed by the roots.

An adequate water supply is therefore necessary for the satisfactory growth of plants. But if the soil is too wet, that is if all its pore spaces are full of water, there can be no room for air. In a soil that is completely water-logged, roots cannot live, and so in permanently wet soils root development is confined to the immediate surface. On the other hand, if all the free space in the soil is full of air there is no water for plants. So in order to have the best conditions for plant growth, the pore space in the soil should be partly occupied by water but not so fully occupied as to exclude air. The pore space of ordinary soils is generally somewhere about 50 per cent., i.e. a cubic foot of soil includes about half a cubic foot of pore space, part of which should be filled by water and part by air.

Injurious substances should be absent from the soil. In some parts of the country, soils are infertile through the presence of compounds of lead, zinc, nickel, or copper. Excessive acidity from atmospheric pollution may affect soils in industrial areas. Flooding by sea water can also affect plant growth. Apart from these obvious effects of injurious substances, there may be other cases in which small amounts of injurious substances affect plant growth. Even where plant growth is unaffected, the nutritive value of grazing may be affected. A striking case of this occurs in the so-called "teart" lands of Somerset, where scouring in cattle has been traced to the presence of molybdenum in the soil and herbage. In the United States, large areas of grazing are adversely affected by the presence of selenium.

There are other factors concerned in plant growth. Plants must have root hold and, if grown as crops, they must be free from the competition of weeds. They must not suffer from fungoid attacks or insect pests. Finally, there may be other factors of which we know little, such as the action of growth-promoting substances in the soil. (*See* Vol. 2, chapter 8.)

For full growth, all the factors mentioned must operate satisfactorily. Any factor that operates unsatisfactorily becomes a *limiting factor*. For example, in a given situation, there may be adequate light, warmth, plant food, etc., but water supply may be insufficient. Water is then the limiting factor, and growth cannot be satisfactory until this deficiency has been remedied. We see, therefore, that the ability to grow good crops is not simply a matter of plant food, but depends on quite a number of other factors.

What does all this mean in terms of actual soil conditions? Some of the factors depend on circumstances external to the soil. Light, the source of energy, and carbon dioxide in the air, the raw material from which most of our plant material is formed, are free for all and more than sufficient for the biggest crops. Suitable temperature depends on the local climate and, although the temperature of the soil may be affected to some extent by management, this factor is mainly outside the control of the farmer.

Water supply is mainly governed by the climate. Water supply and air supply in the soil go hand in hand; excess of moisture means deficiency of air in the soil and vice versa. So we can consider these as one factor and say that moisture in the soil may be either excessive or deficient. Bearing in mind the overriding effect of climate, the actual moisture conditions are greatly affected by the character of the soil, but the farmer can modify these conditions to some extent.

Excessive moisture in the soil is most likely to occur in very wet climates like those of our mountain regions, but even in regions of moderate rainfall, soils may suffer from excessive wetness. This may be due either to the situation of the soil or to its actual nature. All soils, whether light or heavy, in low-lying situations such as the bottoms of valleys or tidal lands, are liable to be wet because of the high level of the ground water. In such cases, the wetness can be cured only by lowering the ground water level and, where sufficient fall cannot be otherwise obtained, this may mean pumping. Great areas in the Fens and in Holland are kept in a satisfactory state by this method. The commoner case is where the wetness is due to the heavy impermeable nature of the soil itself, as in most of our clay soils. Here the wetness can be remedied by ditches or drains.

Deficiency of moisture may be due to the dryness of the climate, but even in moist climates such as our own, soils may suffer from excessive dryness. This is the case where the soil is very sandy or gravelly or where it is very shallow over rock. In such cases the soil cannot retain sufficient moisture to carry a crop through the ordinary intervals between falls of rain.

It should be noted that the moisture conditions in the soil reflect the joint effect of climate, situation, and soil character. In a very wet climate, all but the lightest soils will suffer from excessive moisture; in a drier climate light soils may suffer from excessive dryness, whereas heavier soils and soils in bottoms may be moderately satisfactory.

Finally, we must remember that the same soil may suffer both from excess and deficiency of moisture at different times of the year. Many clay soils that are waterlogged during the winter dry out so badly in the summer that the pasture on them becomes burnt up. Similarly, in the wet hills of Wales, upland grazings may burn up after two or three weeks of drought in summer owing to the thinness of the soil.

Our ideal would be a soil that readily allows the winter rains to drain through but which has sufficient depth to allow of good root development and has sufficient body to retain moisture in the intervals between rain. A well-drained fine sandy loam or silty loam with ground water at 5 to 6 feet below the surface would represent almost ideal conditions. Parts of the Holland division of Lincolnshire show such conditions.

Our fertile soil should have a good supply of plant food. Although there are a dozen or more elements essential for the nutrition of plants, most of these elements are in sufficient supply in ordinary soils. The commonest deficiencies are in one or most of the following: nitrogen, phosphorus, potassium and calcium (lime). The main object in supplying manures and fertilisers (including lime) is to make good deficiencies in these elements. We shall consider more fully the principles underlying the use of manures and fertilisers at a later point in this article.

The presence of substances injurious to plant growth is fortunately the exception rather than the rule. Small areas in mining districts may be affected by zinc, copper, or lead. Soils in the neighbourhood of industries may be affected by acid and other fumes, and some soils in coastal areas may suffer from flooding by sea water, but the areas thus affected form only a very small proportion of our total agricultural area.

Attacks by fungoid diseases and insect pests generally depend on circumstances outside the soil, but certain diseases such as finger-and-toe in swedes and turnips depend on soil conditions and can be got rid of by appropriate treatment. Competition by weeds is held in check by good husbandry, but some seeds are favoured at the expense of crops or grass by undesirable soil conditions. For example, spurrey may prove a troublesome weed in lime-deficient arable, and rushes in waterlogged grassland.

From what has been said, it will be seen that even with a favourable climate and situation, the productivity of the soil depends on a large number of factors, some of which can be controlled by the farmer whilst some are less controllable. Good husbandry consists in managing the soil in such a way that it yields the most profitable return for the money and labour expended, due regard being paid to the maintenance of the general level of fertility.

We must distinguish between the inherent characters of the soil, considered in relation to the climate and situation where it occurs, and those characters impressed on it by management. Most of our agricultural soils are to a greater or lesser extent artificial and differ considerably from their original state. A good farmer, by skilful management can raise the productivity of the soil considerably. A productive soil can be run down in productivity by bad farming. The most striking instances of the effect of management on productivity are given by light sandy soils used for market gardens, as for example, in the Biggleswade district of Bedfordshire. Under grass or ordinary mixed farming, these soils would be of only moderate fertility, but by building up the humus with heavy dressings of farmyard manure and the skilful use of artificial fertilisers they have become highly productive for the growth of vegetables.

Before the outbreak of the 1939-45 war, there were far too many examples of the decline of fertility as a result of bad husbandry. Millions of acres in Great Britain were suffering from the neglect of liming, and almost equally large areas were suffering from neglected drainage. Most of the large area of grassland could be classed as of only second-rate quality.

The inherent characters of the soil largely decide what the farmer can do by his management, but there are some operations lying outside the ordinary compass of management that can alter profoundly the character of the soil. These may be termed *soil improvements*. Whilst the ordinary operations of management involve current expenditure, soil improvements involve capital outlay. Examples of soil improvements are drainage, irrigation works, marling, warping, etc. It is not always easy to draw a hard and fast line between soil improvement and soil management. Thus, if liming has long been neglected, the outlay necessary to restore a farm to a good lime status may be regarded, in a sense, as soil improvement involving capital expenditure, and so it is, to the extent that it is non-recurrent. Reclamation of derelict or waste land is mainly soil improvement, although some of the operations may be ordinary operations of management.

THE USE OF MANURES AND FERTILISERS—(*See* chapter 2).

Good husbandry implies the intelligent use of manures and fertilisers. These dressings are applied to the soil to increase the supply of certain plant nutrients which would otherwise not be in sufficient supply in the soil to yield satisfactory crops. When virgin land is brought into cultivation, for example, when prairie land is broken up or where land is won from forest, big crops are obtained at first, because of the accumulated fertility of the soil. If successive crops are taken and nothing is returned to the soil, yields gradually fall off until they reach a point when the return in crop does not repay the expense of growing it.

This is illustrated in one of the plots on the famous Broadbalk field at

Rothamsted Experimental Station which has grown wheat year after year for a century. The yield has fallen until it now fluctuates around 11 bushels per acre, which, of course, is quite an uneconomic yield under British conditions. Note, however, that this small yield appears likely to be maintained indefinitely. It represents the level at which the losses of plant food by removal of crop and by drainage are just about balanced by the liberation of plant food by weathering in the soil, and in the case of nitrogen, by additions from the nitrogen of the atmosphere through the activity of nitrogen-fixing bacteria.

Now consider what would happen if, instead of selling all the crop off the land, part or all of it were fed to stock, and the manure, including the straw used as litter, returned to the land as farmyard manure. Obviously, the drain on the soil's resources of plant food is greatly reduced and this makes possible a much higher level of production. Indeed, if leguminous crops were included in the rotation to maintain the nitrogen status, and if the lime status were maintained by dressings as required, a moderate level of production might be continued with little or no expenditures on purchased fertilisers. Such was the level with the best farming, before the introduction of artificial fertilisers.

By the intelligent use of artificial fertilisers, production can be raised to a higher level than is possible without fertilisers. The use of fertilisers is demanded also in view of the special needs of certain crops, particularly root crops such as swedes, mangolds, and potatoes, and green crops such as kale and cabbage. Further, the successful establishment of grass seeds generally demands dressings of phosphatic and, in some cases, potash fertilisers. A high level of production, then, demands the use of artificial fertilisers; (*a*) for the maintenance of the plant food status of the soil and (*b*) for the needs of individual crops. If a farmer is aiming at a standard of production implied by such yields as 25 to 30 cwt. wheat per acre, 30 tons mangolds per acre, and 12 tons potatoes per acre, he must not only make good the actual export of plant food from the soil in the crops harvested but also the relatively high losses in drainage and in the making and storage of his farmyard manure.

Food production from our agricultural soils would be greatly increased if the practice of the best farmers were generally followed. It would materially help towards this objective if every farmer adopted a scheme of manuring suited to his type of husbandry. There is no reason why manurial practice should not be greatly improved. An essential step is to get all fields tested for manurial deficiencies. This tells the farmer what fields, if any, are in need of lime dressings. It also shows up any marked deficiencies in phosphate and potash, so that the farmer may know if additional dressings are needed.

The Use of Lime Dressings.[1]—Why are lime dressings applied to

[1] We use the term lime dressings rather than "lime" in order to cover the use not only of burnt lime or ground lime but also of ground limestone, chalk, marl, waste limes, etc. to supply lime to the soil.

the soil? Whilst there is no doubt about the beneficial effects of lime dressings over a large part of our country, somewhat differing views are held as to their mode of action. One view is that lime dressings correct acidity in the soil. Another view is that, like other fertilisers, they make good a deficiency of lime in the soil. Now, it is not easy to decide between these two points of view, because a soil that is deficient in lime is always acid, whilst a soil that is acid is generally deficient in lime. We say *generally* because many soils, particularly those rich in humus under moist climates, can show quite appreciable acidity, as judged by chemical tests and yet show no response to lime dressings. This means that they have sufficient lime for the needs of the crops grown and that if acidity is the actual defect remedied by liming, then its harmfulness must be modified, either by the moist climatic conditions or by the high humus status of the soil.

We shall be quite safe, however, if by lime deficiency we understand that condition of the soil that renders it responsive to dressings of liming materials such as lime, ground limestone, etc. Giving this broad meaning to lime deficiency, we can say at once that it is one of the commonest, if not the commonest of all soil defects. At the beginning of the 1939-45 war it was estimated that the extent of lime-deficient soils in Great Britain was as follows:

England	10 million acres
Wales	2½ ,, ,,
Scotland	4 ,, ,,
	16½ ,, ,,

This estimate does not take into account about 5,000,000 acres of rough grazings, most of which are acutely deficient in lime. The requirements to make good this deficiency were estimated at the equivalent of about 25,000,000 tons of quicklime (CaO).

Lime is continually being washed out of the soil in drainage waters. The amount thus lost depends on the rainfall, but also on the actual amount of lime in the soil. At Rothamsted, where the soil contains a good supply of lime, the annual loss is estimated at 4 to 5 cwt. of lime (CaO) per acre. With soils on or below the borderline of deficiency, i.e. the soils that are dependent for their lime on added dressings, the annual loss is 1 to 2 cwt. per acre. Over most of Scotland, Wales, and England, except in the south-east, soils generally tend to be deficient in lime and unless dressings are given they may become so depleted as to suffer in productivity. In the south-east considerable areas of soil are naturally well supplied, but deficiency is likely on sandy soils.

From what has been said, it is clear that the old practice of liming or chalking which had largely fallen into disuse before the outbreak of the 1914-18 war should be an essential part of good husbandry over most of the country. Since 1937, there has been a Government subsidy on liming materials and the annual use increased from about 600,000 tons to about

4,000,000 tons of liming materials in 1945. Much still remains to be done, because not only have the large areas suffering from lime deficiency to be restored to a satisfactory status, but provision must be made for making good the annual wastage in drainage. It has been estimated that even if all the soils of Great Britain were at a satisfactory lime status, about 2,000,000 tons of lime (CaO) would still be needed annually to maintain them in this state.

Many of the effects of lime deficiency are well known to experienced farmers. Certain crops such as barley, mangolds, and sugar beet are particularly sensitive to lime deficiency and if the soil is short of lime they are liable to fail. Grass seeds, and particularly clovers, do not establish well on lime-deficient soils, whilst old pastures tend to become matted and "hide-bound." Finger-and-toe is liable to affect turnips, swedes, cabbages, etc. on such soils. Lime deficiency decreases the efficiency of added fertilisers, particularly phosphates, which rapidly become "locked up" or unavailable on lime-deficient soils.

The adoption of a sound liming policy on a lime-deficient farm will often lead to a marked increase in productivity. Instances are known to the writer where the stock-carrying capacity of farms has been practically doubled after the soil has been brought to a satisfactory lime status. The improvement is seen in the yield of crops, in the condition of pastures, and in the health and performance of livestock.

Given the importance of maintaining the lime status of the soil, how is the farmer to know when the soil of any one of his fields is in need of lime and how much to apply? There are, of course, certain field indications of lime deficiency. Weeds such as spurrey and corn marigold will arouse suspicion, but should not be accepted as infallible indicators. The presence of a matted benty turf in an old pasture is a fairly safe sign of lime deficiency. Another suspicious sign is the failure, in patches, of lime-loving crops such as barley, sugar beet, or beans. All these indications, however, are open to misinterpretations and the only satisfactory procedure is to get the soil tested for lime. This is done free of charge by the National Agricultural Advisory Service, and thousands of farmers now make a practice of getting their soils tested in this way. On the result of the analysis, the farmer is informed if his soil needs lime and, if so, how much is required. If no tests have hitherto been made, it is advisable to get every field on the farm tested and to draw up a liming programme with the object of bringing the whole of the farm to a satisfactory lime status as soon as possible.

Minor Elements in Crop Nutrition.—The plant nutrients most commonly found to be deficient in soils are lime, phosphate, potash, and nitrogen and it is these elements that are supplied by ordinary manurial dressings. In exceptional cases, however, deficiencies of other elements may occur. These are elements required only in very small amounts and, under ordinary conditions, the supplies of them in the soil are more than adequate. Although the amounts of these minor or "trace" elements

required by crops are relatively very small, the lack of a sufficient supply of any one of them may cause serious depression in yields and even total failures. It should be noted, however, that the fact that a crop is suffering from deficiency of a particular element does not necessary imply that there is a deficient supply of that element in the soil. There may be an actual deficiency in the soil, but it is also possible that the availability of the element may be depressed by some soil condition, or it may be the consequence of an ill-balanced supply of plant nutrients. An example of the first case is the depression of boron availability by an excess of lime in the soil, whilst the second case is exemplified by magnesium deficiency induced by excessive use of potash fertilisers. The diagnosis of these deficiencies is very difficult by ordinary methods of soil analysis and more trustworthy indications are given by the appearance of the crop and, in particular, of the leaves, which show discolorations characteristic of each type of deficiency. The indications can often be confirmed by chemical tests on the leaf material. It should be emphasised that diagnosis of minor element deficiencies is essentially a task for experts and, therefore, when a farmer sees that a crop is unsatisfactory and showing any unusual appearance he should get expert advice. Prompt action can often save a crop. The most commonly occurring minor element deficiencies are in manganese, iron, magnesium, and boron. These are dealt with fully in chapter 2.

In addition to deficiencies affecting the growth of crops, there are certain deficiencies affecting the nutrient value of grazing herbage. *Cobalt deficiency* can cause a disorder known as "pining" in sheep, whilst *copper deficiency* can cause "swayback." Diagnosis is by the symptoms in the grazing animals. These deficiencies are best remedied by the administration of mineral "licks" to the animals likely to be affected.

Soil Analysis for Advisory Purposes.—In order that a farmer may make the best possible use of his land in his own interests and in the interests of the nation, his scheme of manuring should be adapted to his soil and to the type of agriculture practised. An intelligent use of manures and fertilisers, including lime where needed, is an essential part of good husbandry. Although it cannot answer every question, soil analysis can be of great help as a guide to the use of manurial dressings. Above all, it can give guidance as to the use of lime. However experienced a farmer may be, he cannot always decide whether or not the soil of a particular field needs lime, still less how much is required. By basing his liming policy on soil analysis, he can ensure that all his fields are brought to an adequate lime status and avoid the use of unnecessary dressings which, apart from being an unnecessary expense, may actually have an adverse effect on the yields of certain crops. In the same way soil analysis can discover deficiences in phosphate and potash. Unfortunately, no satisfactory analytical methods are known for indicating nitrogen deficiency, but this condition is generally well indicated by the appearance of crops in the field.

Under the National Agricultural Advisory Service, a farmer can obtain, free of charge, a report on any or all of his fields. On this report and with the expert advice available he can base his use of manurial dressings. There is no doubt that if all farmers made full use of this service and based their manurial policy on the best advice available, bigger crops, better grass, and better stock would result and the total output of food from our soils would be materially increased.

RECLAMATION AND IMPROVEMENT OF SOILS

The need for increased food production at the beginning of the 1939-45 war drew attention to the fact that considerable areas of land called for improvement. These included: (1) land in the general category "crops and grass" which had become derelict or had fallen considerably in productivity during the years preceding the war; (2) land formerly in "crops and grass" which, through neglect, had gone into the category of "rough grazings"; and (3) rough grazings, including waste lands that had never been improved. Although considerable progress has been made during the war years in the improvement of lands in the first category, much still remains to be done. A small proportion of the land in the second category has been improved and a negligible amount in the third category.

The most important item in the first category was the large area of inferior grassland. Much of this land had formerly been wheat and bean land, but considerable areas, particularly in Wales, had deteriorated as grassland. The economic causes of this deterioration fall outside the province of this chapter, but so far as actual soil conditions are concerned the principal causes were: (*a*) poor drainage, consequent on neglect of drainage system; (*b*) lime deficiency; and (*c*) phosphate deficiency.

(*a*) Much of this land had been tile-drained. In some cases the tiles were too deep, in other cases the tile system had deteriorated, but there were also large areas where the deterioration in drainage had occurred through the neglect of outfalls and the silting up of ditches. During recent years large areas have been improved, but much still remains to be done. In many cases, cleaning of ditches and attention to outfalls suffices; in other cases new tile systems must be laid down. Large areas can be improved by mole drainage.

(*b*) Lime deficiency was more common in the north and west than in the Midlands and south. Much has been done to remedy these deficiencies, but large areas are still lime-deficient. The possible need for lime dressings must always be considered in schemes for the improvement of these soils.

(*c*) Phosphate deficiency was nearly always present. Phosphatic dressings are essential for the improvement of these soils and the initial dressings must be followed up by maintenance dressings if improvement is to be permanent.

Whilst much of this class of land has carried arable crops during the war years, on a long view most of it is probably more suitable for grass. With skilful management and manurial treatment, grazing quality can be maintained, but it would probably be better, particularly in the west, to count on an occasional arable break in order to seed down afresh. In many cases this break might be simply direct reseeding without cover crop. The heavy soils of the south-east, e.g. in Essex, present a difficult problem, because of the difficulty of seeding down and maintenance of sward in a dry climate.

The second category of soils to be considered for improvement occurs mainly in our hill districts. In Wales, Northern England, and Scotland, there are large areas above the present limit of cultivation that were formerly in a much higher state of productivity. They are in enclosures and are known in different parts as "inby," "intake," or "ffridd" (Wales). In some of these fields corn crops were grown, but in the main they were grass fields and played an important part in the economy of hill farming. At the outbreak of the 1939-45 war, most of this land had gone back considerably and much of it was practically derelict. Considerable areas are covered with bracken, whilst wetter areas are infested with rushes. Lime and phosphate status are both very low.

It is held by many that these lands offer some of the best prospects for improvement and, in many parts of the country, particularly in Wales, some spectacular results have been obtained by ploughing up and reseeding. In some cases very satisfactory crops of oats and potatoes have been obtained. Whilst arable crops generally are not likely to be profitable on such lands, the growth of potatoes for seed is a possibility on account of the comparative absence of virus infection through aphids in the high exposed situations where these lands occur.

The cost of reclamation of this type of land is considerable, particularly where there is a heavy cover of rough vegetation. Lime and phosphate must be given generously, and a satisfactory seed mixture must be used, sometimes with or after a pioneer crop. Using the best methods, fine swards have been obtained, but it must be remembered that these soils are not naturally of high inherent fertility, partly by reason of their general shallowness and partly on account of the situation and climate in which they occur. Had they been naturally of moderate or high fertility, they would not have been allowed to become derelict. These inherent defects still operate, even after they have been reclaimed and, unless management is skilful and manurial dressings are renewed, they are liable to revert quickly to their rough condition. The necessity for this after-care should always be borne in mind when schemes for reclamation are being considered. Whilst there are great areas that might and should be improved, some areas offer better prospects than others.

The third category of improvable soils comprises lands that have never been in cultivation. Among these are the soils of the unenclosed

moorland and hill grazings. The arguments for caution in the reclamation of inby, intake, and ffridd are even stronger in the case of these soils. It is extremely unlikely that any considerable areas of potentially fertile soil have been overlooked by the enterprising improvers of past generations, and in fact, these soils represent the lowest level of natural fertility. The cost of reclaiming them would be greater than in the case of the enclosed lands, the result less certain, and any improvement obtained would be expensive to maintain.

The reclamation of peat has always exercised an attraction for some agricultural improvers. Large areas have, in fact, been reclaimed in the Fen district and are among our best agricultural lands. The Fen peats, however, are lowland peats with high lime status. Most of the unreclaimed peat at the present day is acid peat and this offers far less favourable prospects. After the necessary drainage has been done, often at great expense, there is the cost of the initial cultivations and manuring. In spite of their dark colour, these peats are poor in all manurial constituents. It is, therefore, necessary to give lime, phosphate, potash, and nitrogen. Acid peats have been successfully reclaimed, but it might be argued that the same expenditure on other types of waste or derelict land would have given a better return. The case for reclamation of acid peats, however, cannot always be judged solely on economic arguments.

Sandy wastes include heathlands and coastal sands. Many areas of sandy heath have been in cultivation, but have been abandoned. The extreme poverty of these soils in plant food and their dryness makes reclamation a doubtful proposition. In some cases, however, these soils may be suitable for the development of horticulture, particularly if irrigation is possible. The coastal sands fall into two classes, namely dunes, which are generally too dry for consideration, and the sandy flats with high water-table. These latter, particularly in western districts, might well repay attention if the water-table could be controlled.

There are still some areas of salt marshes, as for example, round the Solway Firth and the Dee estuary, which might be considered for reclamation by endyking. Considerable areas were thus reclaimed in past centuries, and include such fertile soils as those of Romney Marsh in Kent, and Sealand, near Chester.

CHAPTER 2

NUTRITION OF CROPS AND MANURING

By Robert Stewart

The manuring of crops is a subject which affects every farmer in the country, whether he is a dairy farmer in Somerset or a cash-crop farmer in the fens of Lincolnshire. Probably much more attention is given to manuring by the arable farmer than by the grassland farmer, although the latter's developing interest in new leys and in the improvement of grassland tends to increase his interest in the use of manures and fertilizers. The fact that British farmers spend approximately £30 million per annum on fertilizers and an unknown, but probably comparable, amount on farmyard manure is in itself sufficient evidence of their importance. It also suggests that every farmer should endeavour to understand something of the fundamental principles underlying the feeding of crops, even though the subject is highly technical and is becoming more and more so every day.

Twenty or thirty years ago he was told that there were three essential plant foods which had to be supplied in manures and fertilizers and which the chemists called nitrogen, phosphorus and potassium. At that time it was generally implied, although not actually stated, that these three were all that mattered. Since then he has read about a number of "diseases" affecting crops in different parts of the country which have been reported as being due to a deficiency in the soil of one or other of a number of "minor" plant foods such as manganese, boron and iron. These mineral plant foods or "elements" as the chemists call them have, therefore, to be added to the list of those which are of importance in the nutrition of plants.

Although most farmers are quite familiar with the different functions and values of the original triumvirate of nitrogen, phosphorus and potassium, not a few still look on all the different materials supplied by the fertilizer merchant in a sack or bag as just different kinds of the same thing and describe them all as "bag muck." In spite of the picturesque appropriateness of this term it indicates an unfortunate ignorance of the nature and special functions of the different kinds of fertilizers. An attempt will, therefore, be made to explain the fundamental principles of manuring, in addition to describing the different materials which are available and the modern developments in the manufacture and use of fertilizers.

THE FUNDAMENTALS OF MANURING

History does not tell us when some prehistoric farmer first thought of collecting the manure from his cattle and using it to dress his tilled fields

in order to get better crops, although this must have been almost as revolutionary in its time as the introduction of chemical fertilizers a hundred years ago. In between these dates, of course, the knowledge was gradually gained, and applied, of the value of a wide variety of materials such as bones, wood ashes, seaweed, chalk and lime. Although these early types of manure, or "goodings" as they were called in some parts of the country, were used as a result of practical experience, we know some of the reasons for their value as a result of scientific work on plant nutrition and the nature of soils.

The explanation of the practical experience that manures increase the yield of crops is, in most cases, that the system of cropping either removes more of certain chemical elements from the soil or leads to more loss in the drainage water than was the case under the natural vegetation which existed in "pre-farming" times. Nature's balance is upset, therefore, and has to be corrected by the addition of something which will provide the extra amounts of those chemical elements which are removed in crops and by livestock. Generally speaking, the more intensive the system of farming, the more severe is the demand on the soil for certain elements and, hence, the more serious is the degree of disturbance of Nature's equilibrium. Fundamentally, all methods of manuring are, or should be, designed to readjust this condition of unbalance and thus obtain a compromise between Nature's intentions and the farmer's requirements.

Just what the farmer's extra demand on the soil may be in any particular case depends on the kind of crops he is growing, his system of managing his land and the natural fertility of his soil. In some cases the extra demand may fall most heavily on the soil organic matter and, therefore, methods of replenishing this will be of special importance. In other cases the extra demand will be for some chemical element such as nitrogen, phosphorus or potassium and these may be supplied in one or other of several ways.

The maintenance of the organic matter content of the soil may be of importance to the farmer for several reasons. The system of farming he practises may lead to an unnaturally rapid loss of organic matter and this may influence the condition of his soil, either by altering its water-holding capacity, the way air can enter into it, the ease with which he can cultivate it and obtain a tilth, the amount of plant food which the organic matter can supply or store and hold in reserve, or the number and kinds of living organisms such as earthworms, fungi and bacteria which contribute to its natural fertility. On the other hand there are, almost certainly, circumstances where organic matter is relatively unimportant from any of these points of view and the cropping capacity of the soil may be determined largely by other factors, such as the level of subsoil ground water or the amounts of plant food elements naturally present in the soil.

It is probably a true statement that the majority of farmers know more about the food requirements of their livestock than about the food

requirements of their crops. This is possibly due to the fact that the animals' food is all visible and tangible, whereas several important parts of the plants' food are invisible, being either in the air or in the depths of the soil. Also, the feeding of his stock is almost entirely under his own control and he can readily, and in most cases quickly, observe the animals' reaction to changes in feeding practice. With his crops, however, the feeding is partly under the control of Nature and partly under his own, and the trouble is that he does not always know how Nature works and what help she needs from him.

THE FOOD REQUIREMENTS OF PLANTS

All livestock farmers know that different feeding-stuffs have different food values and that some are of special importance for particular purposes. It is recognized that proteins such as are provided in milk, meat, fish and pulse grains, are necessary for growing animals and for milk production; while carbohydrates, i.e. sugary or starchy foods such as cereals, potatoes and roots, are relatively more important for fattening stock. It is also recognized that "pure protein" or "pure carbohydrate" are seldom fed as such and that practically all home-grown or purchased feeding-stuffs contain both these kinds of foods but in different proportions.

Before discussing the food requirements of plants it is necessary to know something about their composition. It is found by chemical analysis that plants contain water, carbohydrates, proteins, fats, colouring matters or pigments, together with smaller amounts of mineral matter including the chemical elements potassium, sodium, calcium, magnesium, iron, phosphorus, sulphur and chlorine and traces of a number of other elements such as manganese, copper, zinc and boron. In a green and growing plant, approximately 75 to 90 per cent. of the total weight of the plant will be water, and of the remainder, the "organic" part, i.e. carbohydrates, proteins, etc., will account for a further 10 to 20 per cent., while the sum total of all the "mineral elements" will generally be less than 5 per cent. and usually between 1 and 3 per cent. The approximate composition of some cereal grains, grass, hay, roots and green crops is shown in the table on page 43.

It will be noted that the cereal grains and hay are fairly similar in composition and that, expressed in this way, potatoes and sugar beet have practically the same composition. The difference between hay and the cereal grains lies in the nature of the carbohydrates, the latter containing much less fibre. Similarly, the difference between potatoes and sugar beet is due to the fact that in potatoes the greater proportion of the carbohydrate is starch, while in sugar beet approximately 75 per cent. of the carbohydrate is sugar.

The organic constituents obviously comprise the great bulk of the dry material of the plant and the mineral elements only a comparatively small proportion. The formation of carbohydrates and proteins by the plant is

due to a complex process, called photosynthesis, which takes place mainly in the leaves under the action of light. The raw materials from which they are produced are the gas, carbon dioxide, which is present in small amount in the air, and water; while the proteins require simple compounds of nitrogen absorbed from the soil in addition. The final products all contain much more energy than the raw materials from which they were formed, as is shown by the heat given out when dry plant material

The Composition of Certain Crops.

Crop	Approximate percentage composition				
	Moisture	Protein	Oil	Carbo-hydrates	Mineral Matter
Wheat (grain)	14	12	2	70	2
Oats (grain)	14	10	5	68	3
Seeds hay	14	12	3	64	7
Pasture Grass (average)	80	3½	1	13½	2
Sugar Beet tops	83	2	½	10½	4
Sugar Beet	76	1	trace	22	1
Potatoes	76	2	trace	21	1
Kale	86	2¼	¼	10	1½

is burnt. The very complex chemical changes taking place within the leaf require the presence of certain catalytic substances, which promote or accelerate the chemical changes, and a supply of energy from the radiation of sunlight. When the carbohydrate and protein have been formed they are "translocated" or moved to other parts of the plant where they are either stored as starch, sugar or protein in roots or seeds or broken down again to liberate energy for the growth and development of other parts of the plant, such as the roots.

Several of the mineral elements found in plants play an important part in this complicated process of production of "organic" matter and calcium, potassium, phosphorus, magnesium, iron and sulphur are all essential for the normal activity of the photosynthetic process. Where one or the other of these is not present in the plant in adequate amount, the deficiency may upset the normal cycle of chemical changes to a degree out of all proportion to the amount of the element, e.g. if the plant cannot obtain traces of iron compounds the green colouring matter in the leaf, called chlorophyll, will not be produced and, since this is a key compound in the absorption of energy from sunlight, the whole process of carbohydrate production is prevented.

So far we have listed carbon dioxide, water and certain mineral elements as the raw materials from which the plant builds up its structure

and substance under the action of light. The first of these is obtained, as already stated, from the air, and the other two are supplied from the soil through the absorbing root system. The roots of plants are, however, made up of living cells and they require energy for their development. This is obtained by the oxidation, or burning up, of a part of the carbohydrate material translocated from the leaves, and carbon dioxide is liberated as the by-product. This action of the root is, as it were, the reverse of the action of the leaf. The root system can only develop, therefore, when a supply of oxygen is available from the soil, and the carbon dioxide can be absorbed by, or liberated from, the soil. This is the reason why aeration of the soil is so important in the growth of crops, and it explains why the roots of most plants will not live in completely waterlogged soil.

The two other main functions of the soil are to supply water to the plant roots and to provide the small, but essential, quantities of mineral elements. The general food requirements of the plant can thus be summarized as follows: oxygen, water and mineral elements from the soil, and oxygen and carbon dioxide from the atmosphere, with energy from the sun's radiation.

The quantities of water, carbon dioxide and those of three of the important mineral nutrients—nitrogen, phosphorus and potassium—actually utilized by average crops of different kinds during a complete growing season are shown in the following table. The quantity of water transpired and of carbon dioxide absorbed by the crops are only approximate extimates, but indicate their order of magnitude in relation to the mineral plant foods.

The Requirements of Crops.

Crop	Assumed yield per acre	Dry Matter in crop	Water transpired by crop	Carbon dioxide absorbed from the air	Absorbed from the soil		
					Nitrogen	Phosphorus	Potassium
Wheat	(20 cwt. grain) (25 cwt. straw)	39 cwt.	590 tons	60 cwt.	52 lb.	11 lb.	27 lb.
Barley	(18 cwt. grain) (18 cwt. straw)	31 cwt.	470 tons	45 cwt.	43 lb.	9 lb.	32 lb.
Oats	(18 cwt. grain) (26 cwt. straw)	37 cwt.	560 tons	55 cwt.	47 lb.	14 lb.	46 lb.
Potatoes	(10 tons tubers) (12 tons tops)	73 cwt.	1,100 tons	120 cwt.	160 lb.	17 lb.	158 lb.
Sugar Beet	(10 tons roots) (8 tons tops)	75 cwt.	1,100 tons	100 cwt.	100 lb.	18 lb.	158 lb.
Cabbage (Drumhead)	(20 tons)	44 cwt.	660 tons	60 cwt.	140 lb.	20 lb.	150 lb.

The table emphasizes that water is the substance required by plants in by far the greatest amounts. A potato or sugar beet crop of the order indicated uses, during the season, water from the soil equivalent to about 11 inches of rainfall. The second substance in order of actual weight required is carbon dioxide from the atmosphere. Since atmospheric air only contains about 3 parts of carbon dioxide in 10,000 parts of air, the "air" requirements are exceedingly large. It can be calculated, for instance, that an average root crop could absorb during the season all the carbon dioxide from a column of air of similar area over 7,000 feet in height, approximately twice the height of Snowdon. Air is, however, plentiful, and moisture supply and the minerals supplied from the soil become relatively much more important, in spite of the fact that in terms of weight the needs of the crop, for minerals at any rate, are measured only in lb. or cwt. per acre.

THE CHEMICAL ELEMENTS IN PLANT NUTRITION

Among the chemical elements which have been mentioned so far as essential for normal plant growth are carbon, oxygen, hydrogen, nitrogen, phosphorus and potassium, and all of these are required in comparatively large amounts. There are, however, other elements always present in the plant mineral matter and which are equally essential for growth. Those occurring in largest amounts are calcium, magnesium, sulphur and iron. The ten elements in these two groups are generally called the "essential major elements" to distinguish them from another group of elements which, although equally essential, are present in plants in very small amounts. The elements manganese, boron, copper, zinc and molybdenum are now recognized as being necessary to plant growth and are referred to as "essential minor elements," or, more frequently, "trace elements."

The importance of these trace elements has been recognised only comparatively recently and in most cases was discovered from the investigation of physiological diseases in crops where one or other of these trace elements was found to be deficient, i.e. present in abnormally low amounts. It is, perhaps, rather unfortunate that the trace elements have become so definitely identified in the farmer's mind with deficiency diseases, since he may be inclined to think that, provided his crops do not show any symptoms of the disease, they are of no importance. In other words, he may have the impression that they are only associated with diseases, whereas, in fact, they are just as essential to normal healthy crop growth as are the major elements such as nitrogen, phosphorus and potassium which he supplies in manure and fertilizers. It is, however, a fact that the great majority of soils are capable of providing, from the reserve of mineral elements in the soil, all that the plant requires of these trace elements. This means that fertilizer additions of these elements are required only when the soil supply is abnormally low or when some condition in the soil renders the plant unable to obtain what is necessary.

Plants contain many other chemical elements in addition to the ten major and five trace elements listed above, but, so far, it has not been proved that they are necessary for healthy plant growth. Plant physiologists have an open mind on this matter, particularly with reference to one or two elements, and it is possible that the list of essential elements may yet be extended to include some of the doubtful ones. The elements which are apparently not essential, although almost always present in the plant in larger or smaller amounts include silicon, sodium, chlorine, aluminium, titanium, nickel, cobalt and iodine.

It may be of interest to note that this list of unessential elements contains several elements—cobalt, iodine and chlorine—which are recognized as essential elements in animal nutrition but not in plant nutrition. It follows from this that these elements may be of economic importance to the farmer since they may affect the health of his stock although they do not affect his crops. An instance of this kind is the disease of sheep, known in this country as "pining" and occurring in various parts of Scotland, which is due to a deficiency of cobalt in the natural herbage. There is no evidence, however, that this cobalt deficiency has any direct effect on the health of the pasture plants. Instances are also known where an excess of a chemical element in a plant leads to a disease in animals due to its toxicity to the animal. An example of this is the cattle scouring disease on "teart" land in Somerset and some other areas in the West of England, which is due to excess of molybdenum in the herbage. An excess of another element, selenium, has been proved as the cause of "alkali disease," affecting horses, cattle, pigs and poultry in certain areas of the mid-Western States of the U.S.A.

These cases have been mentioned to show that plants and animals are not exactly alike in their needs of mineral elements. The grazing animal normally obtains its supply of essential elements from the natural herbage, but it may develop disease on apparently healthy pastures, and the disease can be due either to a deficiency of an element in the herbage or to the presence of a toxic excess of another. Normal, healthy crops may or may not mean, therefore, normal, healthy stock.

THE MAIN FUNCTIONS OF CHEMICAL ELEMENTS IN PLANT NUTRITION

Space does not permit a detailed account of the physiological functions of all the elements essential to plant growth, but the following notes summarize their main effects. Carbon, hydrogen and oxygen, which together form a large part of the dry matter of all plants, can be considered as the bricks from which the plant structure is built up with the other essential elements acting as keystones and mortar which bind them into recognisable habitations.

Nitrogen is a constituent of proteins and several other vital constituents of the plant, including chlorophyll. The size and bulk of the

plant is largely governed by the nitrogen supply in the soil and, therefore, the rate of growth and final crop yield are also related to the amount of nitrogen. A deficiency of nitrogen is reflected in thin weak growth, small light green or yellow-green leaves, poor tillering of cereals and early maturity. An excess of nitrogen tends to produce plants with large dark green leaves which are susceptible to attack by fungus diseases, and it delays final ripening of the crop. Nitrogen is absorbed from the soil either as nitrate or as ammonium, but most plants seem to require the former rather than the latter.

Phosphorus performs a number of functions in the plant and it is concerned in carbohydrate production and respiration and cell division. If the supply of phosphorus is deficient it affects growth in much the same way as nitrogen deficiency, but the colour of the leaves tends to be bluish-green rather than yellow-green. Phosphorus stimulates the growth of the root system and also leads to early maturity of the crop. It is of special importance, therefore, on heavy soils and in periods of drought, due to its influence on root growth, and in regions of high rainfall due to its effect on early ripening. Excess of phosphorus seldom occurs in farming practice, although under intensive systems of cropping and manuring, particularly under glass, there is the possibility of this happening. Phosphorus is absorbed from the soil as phosphate.

Potassium.—The specific functions of this element are still not fully known, but it is connected in some way with the efficiency of the leaf as a carbohydrate producer. It also plays a part in the formation of nitrogenous compounds and also of oils and fats in the plant. An adequate supply tends to render the crop more resistant to drought and to disease, and it also seems to increase the frost resistance of the plant. An excess tends to delay maturity. A deficiency leads to a squat type of growth and to marginal scorching of the leaves. Potassium is absorbed from the soil as potassium ions.

Calcium helps to maintain a chemical "balance" within the plant by combination with organic acids and it also plays a part in the movement of carbohydrates from one part of the plant to another. A deficiency of calcium leads to the death of growing points and shoots, and to scorching and premature death of leaves. A deficiency only occurs on acid soils, but the typical symptoms of acidity may not be due so much to calcium deficiency as to toxic amounts of other elements, e.g. manganese. Calcium is absorbed by the plant as calcium ions.

Magnesium is a component of chlorophyll and, therefore, essential for production of carbohydrates. It is also concerned in the formation of phosphorus compounds and is especially important for plants with a high oil content in their seed. A deficiency produces definite leaf effects, either yellowing or browning between the veins, and early loss of leaf. Magnesium deficiency may be induced by excessive potash manuring or occur on very acid soils together with calcium deficiency. The deficiency is,

perhaps, rather more frequent in this country than was at one time suspected. Brassica crops, potatoes, fruit trees and tomatoes are among the more susceptible crops. Magnesium is absorbed by the plant as magnesium ions.

Iron is connected with the formation of chlorophyll and performs certain other essential functions of a chemical nature in the plant. Most soils contain ample reserves of iron for adequate nutrition, but a deficiency can arise on alkaline soils probably because the availability of the iron is reduced. Perennial crops such as fruit trees are most commonly affected by the deficiency. The leaves of growing points and shoots are mottled green in colour or they may be almost completely bleached. The deficiency, once it develops, is very difficult to correct by soil treatment and the injection into the plant of iron compounds is more satisfactory as a control measure. Iron is absorbed by the plant in the oxidized state as ferric ions.

Manganese is associated, possibly along with iron, in a number of oxidation-reduction reactions in plants and also with carbohydrate production. A deficiency of manganese has been shown to be quite widespread and to affect, in particular, oats, sugar beet, garden beet, mangolds, potatoes, peas, spinach and some fruit crops. The appearance of deficiency symptoms is associated with a combination in the soil of high lime status and high organic matter, or with the presence of a high water table in calcareous alluvial soils. Excessive liming of fen type peat and other highly organic soils can induce the condition. An excess of manganese in the plant has been demonstrated on acid soils and some of the plant symptoms considered typical of "acidity" are probably due to the toxic effect of excess manganese. Manganese is absorbed from the soil as manganous ions.

Sulphur is a constituent of some of the plant proteins and other nitrogen-containing compounds. It is seldom deficient in British soils, but a deficiency has occurred on very poor soils low in organic matter. The symptoms in the plant are similar to those due to nitrogen deficiency. Sulphur is absorbed as sulphate and this is present in several fertilizers, such as superphosphate, sulphate of ammonia, etc., in sufficient amount generally to supply all that is required.

Boron is apparently intimately related to calcium in the plant, but the complete functions of this element are not clearly understood. It is important to leguminous crops since the root nodule organisms fail to develop in its absence. A deficiency of boron has been proved to affect sugar beet, mangolds, swedes, garden beets and several brassica crops, especially cauliflower. The symptoms almost invariably affect the growing points of the plant or show as a breakdown in the storage system, particularly with root crops. The deficiency disease is described as "Heart Rot" in sugar beet, mangolds and garden beet, and "Raan" in swedes and turnips. Cauliflowers develop a browning of the curd and a hollow stem. It is found on soils derived from both the Old and New Red Sand-

stones, Chalk, and in the Fens, under alkaline conditions due to excessive liming.

The functions of the other essential trace elements—copper, zinc and molybdenum have not been completely investigated, but they act in some ways as "catalysts" or controlling agents in certain chemical changes within the plant. So far, they have not been shown to cause any deficiency diseases in this country, although these have been described for several crops abroad. There is some evidence that zinc may be low in some Romney Marsh soils since improved yields have followed dressings of zinc compounds. In a few localities, chiefly around old lead and zinc mining areas, plants have been found to contain toxic amounts of zinc and to show symptoms very similar to, if not identical with, those of iron deficiency.

Although all these fifteen elements are essential for the proper growth of a normal healthy plant, it is fortunate that most soils can supply a considerable proportion of most of the major elements and all that is required of the trace elements. For most of the latter it is, in fact, un*desirable to supply more than the plant's requirements since excessive* concentrations in the soil of these trace elements can be toxic and lead, not to better, but to poorer crop growth and yield. For the majority of crops and soils the elements which may be deficient are nitrogen, phosphorus and potassium, while calcium (in the form of lime) is frequently required to counteract the effect of soil acidity. The maintenance of soil organic matter is generally important from its effect on soil structure and moisture-holding capacity. The manures and fertilizers necessary for maximum yields under normal farming practice need only provide some part of the organic matter requirement and supplement the nitrogen, phosphorus and potassium supply in the soil. Where deficiencies of other major elements or of the trace elements are found to occur the necessary treatment can be added to the normal manurial scheme.

MANURES AND FERTILIZERS

The foregoing account of the functions of the chemical elements in plant nutrition dealt with the major and minor essential elements, and it was stated that, in most cases, only three—nitrogen, phosphorus and potassium—were required as fertilizer elements and, therefore, as constituents of fertilizers. Farmyard manure, being derived from plant materials, contains these three elements and also many of the other essential elements and can be described as a complete plant food or fertilizer. It may not, however, supply the necessary amounts of one or more of the nutrient elements to meet the full requirements of certain crops or soils. The amount of manure produced in England and Wales is estimated to be about $1\frac{1}{2}$ tons per acre of arable land and permanent grassland. It will be shown later that the production of manure is at very different levels in different parts of the country and quite insufficient in many of the important crop-growing areas to provide the full plant food requirements. The need

arises, therefore, to supplement it with materials containing one or more of the three main nutrients or to provide mixtures of materials which will supply all the plant food needs of crops grown without manure.

The long-term rotation experiment at Saxmundham, in Suffolk, has been described by A. W. Oldershaw (*J. Roy. Agric. Soc. England*, 1941, 102, 136-155) and provides definite evidence that a dressing of farmyard manure once in a four-course rotation at a rate equal to 2½ tons per acre per annum, i.e. 1 ton more than the average rate of production in the country, is insufficient to maintain more than moderate yields, and that the yields can be substantially increased by the addition of extra plant food in the form of fertilizers. The classical field experiments at Rothamsted prove very clearly the value of fertilizers in the absence of manure in maintaining a high level of yield over a long period of years. The average effect of fertilizers on the yield of different crops is described later under "Fertilizers and Crops," on the evidence provided by a large number of single-year fertilizer experiments. Both the long-term rotation experiments and the short-term fertilizer trials provide conclusive proof of the need for supplementary plant food in the form of fertilizers under British systems and conditions of farming.

Reference must be made to the belief held by some that chemical fertilizers poison the soil, injure the quality of crops and lead to disease in animals and human beings. The claim has also been made that the use of fertilizers leads to soil erosion, apparently in ignorance of the fact that those areas in continental regions where soil erosion has been most serious have used little or no fertilizer of any kind. Much of the confusion of thought on this matter arises from the use of the terms "natural" and "artificial" as applied to manures and fertilizers, when what is really meant by the two terms is "biological" and "chemical." Farmyard manure, as produced and used on farms, and compost are no more "natural" materials than superphosphate or sulphate of ammonia if the correct meaning of the adjective—"pertaining to, or produced by, nature"—is implied. Man has played a part in the production of each, but in some cases other living organisms such as plants, animals, fungi or bacteria have also been involved. Such products can correctly be described as "biological." In other cases the materials have been produced by man from substances occurring in Nature by purely chemical processes without the help of other living organisms, and are correctly described as "chemical." The chemical properties of matter are just as much a part of Nature's scheme as the biochemical functions of living organisms, and the chemically-produced materials are, therefore, no more "unnatural" than farmyard manure or compost.

The basis of the argument that chemical fertilizers are harmful, whereas manures and composts are essential to soil fertility and the growth and health of plants, is the belief that living organisms must play a part in the production of plant foods and in the maintenance of soil fertility. So much

has already been written on this subject that there is no point in repeating here all the points in the argument. E. B. Balfour's book, "The Living Soil," states the case for the protagonists of the biological or "organic" theory to which a reasoned reply has been given by Donald P. Hopkins in his book, "Chemicals, Humus, and the Soil." W. G. Ogg and Hugh Nicol have summarized and discussed the opposition to the use of fertilizers in their article on "Balanced Manuring" (*Scottish Journ. Agric.*, 1945, 25, No. 2).

It cannot be claimed that all the principles of plant nutrition or the part played by living organisms in the highly complex matter of soil fertility are at present known and understood, but the established facts do not provide any evidence that chemical fertilizers are necessarily harmful to either plant or soil. There is still much to be learnt about the part played by micro-organisms in the production of fertile soils and about the interactions, if any, between the ever-changing micro-organism populations in the soil and the chemical characters of their environment. Unless such new knowledge provides convincing evidence against the use of chemical substances as fertilizers there is no justification for any change in established practice in view of the mass of experimental results and practical experience that chemical fertilizers are essential to maximum production of agricultural crops.

Before describing the variety of manurial and fertilizer materials used on the farm, it is necessary to define the meaning of the terms "manure" and "fertilizer," since there is some confusion in their use. The term "fertilizer" does in fact have a legal meaning in that a number of substances are specified as such in the Schedules to the Fertilizers and Feeding Stuffs Act (1926), and when sold to the farmer under that description, the requirements of that Act must be satisfied by the seller. But there is still a certain confusion in farmers' minds about the two terms, since a "manure" may be a fertilizer, but a "fertilizer" not a manure when these words are used in a certain sense. It is becoming customary, and the practice will be adopted throughout this chapter, to describe as "manures" materials which supply *substantial* quantities of organic matter to the soil in addition to a certain amount of plant food, and to use the term "fertilizers" for those substances which supply one or more of the chemical plant food elements with, or without, a *small* amount of organic matter. For example, bone meal would be described as a "fertilizer" because the amount of humus-forming material it contains is small, whereas sewage sludge would be described as a "manure" because its main value is as a source of organic matter, and its content of plant food elements is of secondary importance.

Manures, therefore, are taken to mean substances which supply food elements to the plant and organic matter to the soil in an amount sufficient to affect its physical or biological condition. In other words, they supply energy to the soil as well as chemical food elements. The value of manure to the farmer may depend on whether the organc imatter or the plant food it contains is relatively the more important, and this will, in turn, depend

on the type of soil, its management, and the system of farming. In areas where long leys are part of the rotation, manures, as suppliers of organic matter, may be of little importance, although they may be most valuable sources of plant food. On the other hand, the mainly arable, cash-cropping farm may require manures mainly as soil improvers and the plant food value may be relatively much less valuable. It is also proposed to divide "fertilizers" into two classes—chemical and organic—according to whether they are products of chemical manufacturing industry, or are products or by-products of animal or vegetable origin. This classification cannot be 100 per cent. accurate since a few materials, e.g. nitrate of soda, may be secondary products of animal origin or be produced by chemical manufacturing processes.

When describing manures and fertilizers it is necessary to adopt some method of expression of their plant food value. The chemical elements of plant foods can be provided in a variety of materials of widely differing composition, and some uniform method must be chosen. Logically, the standard should be the amount of the elements themselves which are present in the fertilizer material, irrespective of the form of chemical compound in which they occur. Very few subjects, however, whether agricultural or otherwise, are treated in a completely logical manner, and custom and tradition play a part in deciding the method of treatment. When the first manufactured or "chemical" fertilizers were produced, the nitrogenous compounds were expressed in terms of "ammonia" (NH_3) probably because this was the basis of one of the new materials—sulphate of ammonia. Materials containing phosphorus were described as containing so much "bone phosphate" or "tri-basic phosphate of lime," more correctly described chemically as tricalcium phosphate ($Ca_3(PO_4)_2$). For potassium compounds, the chemist's term "potash" was used, representing the oxide of potassium (K_2O) since this was the customary method of expression used by analytical chemists. Fertilizer composition was thus expressed in terms of ammonia, phosphate of lime, and potash, although in most cases these chemical compounds were not present as such in the material described.

This illogical method has persisted, although with two important changes. The Fertilizers and Feeding Stuffs Act (1893) made official the description of nitrogenous compounds in terms of nitrogen (N). The second change arose from the Act of 1926 in which phosphorus compounds were defined in terms of phosphorus pentoxide (P_2O_5), loosely termed "phosphoric acid," while it left potassium compounds to be described in terms of potash (K_2O). There is no more justification for this system than for that which it superseded, but it has become the general custom and must, unfortunately, be adopted throughout this chapter. The further change to "N," "P," and "K," the chemical elements, must await the pleasure of some future, more logically and chemically-minded legislators.

There is a definite quantitative relationship between equivalent weights of different chemical compounds of any one element, so that it is merely a matter of calculation to transform a given amount of, say, ammonia (NH_3) into nitrogen (N). The equivalent values for the different forms of expression of nitrogen, phosphorus, and potassium are as follows, taking the present customary form as 100.

100 parts N $=$ 121·4 parts ammonia (NH_3)
100 parts P_2O_5 $=$ 218·4 parts tricalcium phosphate ($Ca_3(PO_4)_2$)
$=$ 43·7 parts phosphorus (P)
100 parts K_2O $=$ 83·0 parts potassium (K)

Again, because of established custom, the term "potash" will be used instead of potassium oxide (K_2O), and "phosphoric acid" instead of phosphorus pentoxide (P_2O_5). The use of the latter is particularly unfortunate since the chemical substance ortho-phosphoric acid (H_3PO_4) can be used as a fertilizer under certain conditions. The term "phosphate" will be used in a general sense to denote a class of material containing phosphorus.

TYPES OF MANURES AND FERTILIZERS

Farmyard Manure.—By far the most important sources of plant food on the farms in this country are the various types of farmyard manure produced from different classes of livestock. They consist of the whole or part of the solid and liquid excreta of bullocks or cows, young stock, horses, pigs and poultry, mixed with a varying proportion of litter such as straw, peat moss, sawdust or bracken. The composition, and hence the value, of farmyard manure varies widely and depends on (a) the class of stock, (b) the material used as litter, (c) the proportion of liquid excreta (urine) retained in the manure, (d) the kind and amount of food fed to the stock, and (e) the methods of making and storing the manure. With all these variables, it is obviously impossible to do more than state the generally accepted average composition of manure from different classes of stock, while indicating how this average is affected by the other factors which influence its composition and quality.

The Average Composition of Farmyard Manure.—The value of farmyard manure is generally assessed on the basis of the amount of organic matter and plant foods, particularly nitrogen, phosphoric acid and potash, which it contains. Data are given below for these four main constituents, but it should be remembered that manure contains other plant food elements derived from the animal's food or the litter. These may be of importance in certain circumstances, and their presence makes it difficult to obtain a true comparison of the plant food values of dung and mixtures of chemical fertilizers. In the majority of cases, however, the fertilizer value of manure can be assumed to be due mainly to its content of nitrogen, phosphoric acid and potash. The following table gives the average composition of different kinds of farmyard manure.

These average values are subject to very wide variation, but they serve to show some of the more important differences between manures from different classes of stock. The manure lowest in plant food value is that from dairy cows, while that from fattening bullocks is the richest, apart from poultry manure. The last is, in fact, by far the richest of all, both as regards organic matter and plant foods, particularly nitrogen and phosphoric acid.

The Average Composition of Farmyard Manure.

Manure from:	Percentage Composition			
	Organic Matter	Nitrogen (N)	Phosphoric Acid (P_2O_5)	Potash (K_2O)
Dairy Cows ..	15	0·40	0·20	0·40
Fattening bullocks	20	0·60	0·25	0·70
Horses	22	0·50	0·23	0·50
Pigs	14	0·45	0·20	0·60
Poultry	30	2·00	1·20	0·60

An approximate general average for the amounts of organic matter and plant foods supplied by a dressing of 10 tons of good quality cow manure or average bullock manure would be:

Organic Matter	1·5 to 2 tons
Nitrogen	1 cwt.
Phosphoric Acid	0·5 cwt.
Potash	1 cwt.

Crowther and Yates have shown, however, from their examination of the results of field experiments that a 10-ton dressing of dung is equivalent in fertilizer value to supplying 0·4 cwt. phosphoric acid and 0·6 cwt. potash to the immediately following crop. In other words, the phosphoric acid of dung appears to be about 80 per cent. available to the first crop while the potash availability is about 60 per cent. The proportion of available nitrogen is variable, but much smaller and probably about 30 to 40 per cent. for average dung. This means that farmyard manure, as a source of plant food for the following crop, cannot be valued on the basis of its total contents of nitrogen, phosphoric acid and potash, but on a fraction of these, this fraction being round about one half to three-quarters for phosphoric acid and potash and about one-third for nitrogen.

The Factors Affecting the Composition of Farmyard Manure.—The kind of animal has already been mentioned as affecting the gross composition of the manure, but the quality or type of manure is also dependent on the animal. Horses and poultry produce dry "hot" dung which rapidly ferments and which contains a relatively high proportion of "active" or

available plant food. Manure from pigs and dairy cows is "cold" and ferments much more slowly. Since a smaller proportion of the total plant foods are "active" they are slower in action as a fertilizer. Manure from fattening bullocks is intermediate in type.

The method of making and storing the dung also influences its quality and composition. The greater proportion of the nitrogen and potash voided by the animal is present in the urine, whereas most of the phosphoric acid is present in the solid excreta. The nitrogen and potash contents of the manure depend, therefore, on what proportion of the urine is absorbed by the litter and whether the dung is exposed to leaching by rainfall or is produced under cover. The nitrogen content is also influenced by the type of fermentation in the manure. This, in turn, is governed by the amount of air present and is less in a well-consolidated heap than in one which is relatively loose and dry.

The litter has some effect on the composition of the resulting manure, apart from its ability to absorb the urine, due to its own composition. Straw, for instance, contains considerably more potash than peat moss or sawdust, while bracken contains considerably more nitrogen than the other common kinds of litter. Well-made and well-rotted dung is richer in both total and available plant foods than fresh, long manure. Since it may require anything from 1½ to 2 tons of fresh manure and litter to produce 1 ton of well-rotted manure, the amounts of plant food actually conserved in the manure will be less with the rotted than with the fresh manure due to the unavoidable losses during storage.

Liquid Manure.—The urine of animals gives a very important contribution to the manurial value of yard manure and this is due to the fact that it contains nearly all the potash and much of the nitrogen voided by the animal. Where insufficient litter is used to absorb the urine, and no provision is made to collect the surplus, there can be a serious loss of the manurial value of the feeding-stuffs used. The efficient conservation and proper utilisation of urine offers probably the greatest opportunity to many farmers, particularly dairy farmers, to economize in their fertilizer requirements. The use of liquid manure, while very attractive on paper, presents a number of serious practical difficulties which probably account for the fact that comparatively few farmers in Britain make much use of urine in this way. It is necessary to provide airtight storage tanks to which the urine can be led without much dilution by washing-down water and to have a pumping system and tank cart for its distribution on the field. Where these facilities have been provided, there is no doubt that liquid manure can be a very useful source of soluble nitrogen and potash fertilizer particularly suitable for most root and green crops and for application to meadows and temporary seeds.

Fresh urine from dairy and fattening cattle will contain about 1 per cent. of nitrogen and potash, i.e. approximately 10 lb. per 100 gallons, but negligible amounts of phosphoric acid. Since there is generally a certain

degree of dilution and some loss of nitrogen value due to fermentation in the storage tank the manurial value in most cases will be less than this, and probably about 4 to 5 lb. nitrogen and 5 to 6 lb. potash per 100 gallons. At this concentration an application of 1,000 gallons per acre would be equivalent in fertilizer value to a dressing of approximately 2 cwt. sulphate of ammonia and ¾ to 1 cwt. muriate of potash.

Fertilizers.—Although very many substances, both organic and chemical, possess some fertilizer value, those in common agricultural use are much more limited in number and a comparative few provide the major portion of the total plant food supply. The more generally used fertilizers are listed in the table facing this page under the usual agricultural names. They are grouped according to the plant food element, or elements, they supply and the main chemical constituents are given together with the percentages of N, P_2O_5 and K_2O contained in the normal commercial materials. For those fertilizers containing only the one plant food element, the relative costs are shown by unit prices, i.e. the prices for 1 per cent. of a ton, calculated on the basis of the "delivered to station" price for 6-ton lots during March/June 1948. For those providing two plant food elements, the average price per ton during the same period is given.

Nitrogenous Fertilizers. *Sulphate of Ammonia.*—This is by far the most important source of fertilizer nitrogen in Great Britain and the supply includes by-product and synthetic material, the latter forming the greater part. It is a comparatively pure chemical produced in crystalline form with the crystal size varying somewhat, and the larger crystal types are rather easier to handle for direct application in the field. It tends to cake or set hard under damp conditions, and should, therefore, be kept as dry as possible during storage. Approximately 60 per cent. of the total production is used for compound fertilizer manufacture and 40 per cent. for use as a straight fertilizer or mixed on the farm.

Nitrate of Soda.—The consumption of nitrate of soda in 1938-39 in Great Britain was about 45,000 tons, but the supply was severely limited during the war years. The post-war importations have been restricted to about 35,000 to 40,000 tons. It is supplied either as a coarse crystalline material or in granular form and the latter is more convenient to handle and store since it is rather less deliquescent. Potash Nitrate is another Chilean product, but only a small amount is available, although it is valued as a quick-acting fertilizer supplying both nitrogen and potash.

"*Nitro-Chalk.*"—This proprietary compound is a mixture of approximately 45 per cent. ammonium nitrate and 55 per cent. precipitated calcium carbonate and is supplied in granular form. It is the only home-produced nitrate fertilizer available in any quantity and contains half its nitrogen in the nitrate and half in the ammonium form. It is a popular top-dressing fertilizer which is easy to handle and stores reasonably well, provided it is kept dry.

Cyanamide.—Supplies of cyanamide were available prior to 1940, but

Chemical and Organic Fertilizers in general Agricultural use.

Fertilizer	Main chemical constituent	Plant food content	Price per unit of plant food or per ton
(a) *Containing Nitrogen only*			
Sulphate of Ammonia	Ammonium sulphate	20·6% N	10/2 per unit
Nitrate of Soda (Chilean)	Sodium Nitrate	16·0% N	13/9 per unit
"Nitro-Chalk"	Ammonium nitrate	15·5% N	13/2 per unit
Cyanamide	Calcium cyanamide	20·6% N	*
(b) *Containing Nitrogen and Potash*			
Potash Nitrate (Chilean)	Sodium nitrate Potassium nitrate	14 to 15% N 10 to 15% K_2O	£15 6 0 per ton
(c) *Containing Nitrogen and Phosphate*			
Ammonium Phosphate (Imported)	Mono-ammonium phosphate	11 to 12% N 48% soluble P_2O_5	£21 7 0 per ton
(d) *Containing Phosphate only*			
Superphosphate	Mono-calcium phosphate	15 to 19% soluble P_2O_5	6/7 per unit
Triple superphosphate	Mono-calcium phosphate	44 to 48% total P_2O_5	*
Basic Slag, High grade	Complex calcium silicate-calcium phosphate	18 to 20% total P_2O_5	4/1 per unit
Basic Slag, Low grade		6·0% total P_2O_5	6/5 per unit
Ground Mineral Phosphate (= Ground North African Phosphate)	Calcium phosphate (Apatitic)	25 to 30% insoluble P_2O_5	4/3 per unit
(e) *Containing Potash only*			
Muriate of Potash	Potassium chloride	50 to 60 % K_2O	4/7 per unit
Potash Manure Salt	Potassium chloride	40% K_2O	4/8 per unit
Sulphate of Potash	Potassium sulphate	48 to 50% K_2O	7/10 per unit
(f) *Organic Fertilizers*			
Hoof and Horn Meal	Animal protein	12 to 15% N	57/8 per unit
Dried Blood	Animal protein	12 to 14% N	60/- per unit
Meat and Bone Meal (Tankage)	Animal protein and calcium phosphate	6.5 to 7.5% N 11 to 18% insoluble P_2O_5	£25 0 0 to £33 0 0 per ton
Bone Meal	Animal protein and calcium phosphate	3 to 5% N 20 to 23% insoluble P_2O_5	£21 5 0 per ton
Steamed Bone Flour	Mainly calcium phosphate	About 1·0% N 25 to 27% insoluble P_2O_5	6/6 per unit

* Not quoted 1947-48.

only very small importations have been possible in the post-war period. Originally a dusty, dark-coloured powder its physical condition has been improved by oiling and even further by granulation. It had an important use as a weed-killer and also as an accelerator for compost making, but it was not a major source of fertilizer nitrogen in Britain.

Ammonium Phosphate.—This is the basis of an important series of proprietary concentrated complete fertilizers manufactured in this country, and it was also imported from America during the war years. Supplied in granular form it handles and stores very well.

Organic Nitrogenous Fertilizers.—The most important of these are (1) hoof and horn meal and (2) dried blood, but their very high price practically prohibits their agricultural use. At the prices ruling in 1947-48 for these organics it seemed difficult to justify their use even for the more highly-priced horticultural crops. Their special value depends on their slow decomposition in the soil and on the fact that they can be applied quite liberally to growing crops without fear of damage.

Consumption of Nitrogenous Fertilizers.—The following data for the agricultural consumption of nitrogen in the British Isles have been extracted from the 27th Annual Report of the British Sulphate of Ammonia Federation, Ltd. The following table gives the total consumption in 1,000 tons of nitrogen and the quantities provided by sulphate of ammonia and by the other forms, including nitrate of soda, ammonium phosphate, "nitro-chalk" and organics, and the percentage of the total consumption provided by sulphate of ammonia.

Agricultural consumption of Nitrogen in British Isles (Thousand tons).

Fertilizer Year	N. as Sulphate of ammonia	N. in other forms	Total N.	Sulphate of Ammonia as % of Total
1913-14	12·3	12·4	24·7	50
1918-19	55·4	3·9	59·3	93
1923-24	29·3	7·8	37·1	79
1930-31	33·8	10·4	44·2	76
1938-39	44·4	23·2	67·6	66
1943-44	137·0	43·0	180·0	76
1945-46	114·3	49·5	163·8	70
1946-47	115·7	47·7	163·4	71

The consumption of nitrogen was less than 25,000 tons per annum prior to the 1914-18 war, but more than doubled by 1918-19 before falling again in the 1920's. By 1930 it had started to rise again, and before the 1939-45 war amounted to approximately 68,000 tons, of which

two-thirds were accounted for by sulphate of ammonia and about one-tenth by nitrate of soda. There was a very rapid rise after 1940 and sulphate of ammonia provided the greater part of the increase. The consumption in 1946-47 represented approximately 0·18 cwt. nitrogen per acre of arable land, which was rather more than double the pre-war quantity, but was still much below the level of consumption in several European countries.

Phosphate Fertilizers. *Superphosphate.*—This is the most important material providing fertilizer P_2O_5 and it occupies much the same position in the phosphate field that sulphate of ammonia does in the nitrogen field. It is produced as a friable powder which handles and stores well under average conditions. The different grades of commercial superphosphate on the market are due to the variability in the grades of rock phosphate from which they are made. In Britain superphosphate is assessed on the basis of water-soluble P_2O_5 content and in practically all present-day superphosphate about 95 per cent. of the total P_2O_5 is present in the water-soluble form. It is sold on the basis of water-soluble P_2O_5 content. More than half the total production, which slightly exceeded 1,000,000 tons in 1947-48, is used in the manufacture of compound fertilizers.

Triple Superphosphate.—Although this material has been manufactured in very small amounts in Britain in the past, it did not become known to farmers generally until the 1939-45 war period when it was imported in substantial amounts from America. Its high concentration and good physical condition soon made it popular. Although the degree of water-solubility is lower than in ordinary superphosphate, most of the P_2O_5 is readily available and it is equally effective as a fertilizer. Its production on a large scale is expected to start in Britain in 1950.

Ammonium Phosphate.—This is the only other common fertilizer material containing water-soluble phosphate and most of the British production is in the form of concentrated compounds. During the 1939-45 war years it was imported and found ready favour with farmers, but importations were limited in post-war years.

Basic Slag.—This popular fertilizer is the finely-ground slag which is a by-product in the making of steel by the Bessemer converter and the basic open-hearth processes. The P_2O_5 content and availability of the phosphate compounds present in the slag depend on the phosphate content of the original iron ore and the type of process used in the making of the steel. The solubility of the ground slag in a 2 per cent. solution of citric acid is a reliable indication of its fertilizer value and since 1943 a warranty of citric-solubility has been given by manufacturers. All slags should show a fineness of grinding of at least 80 per cent. through the 100-mesh sieve and the higher-grade slags a total P_2O_5 content of 18 to 20 per cent. This ranges downwards to 6 per cent. or less, but most slags lie within the range of 8 to 20 per cent. P_2O_5. The most valuable slags are those with a citric-solubility of 80 per cent. or over, and it should be noted that solubility is not directly related to total P_2O_5 content. Fineness of grinding, content of

total P_2O_5 and degree of citric-solubility are the three criteria of fertilizer value for all basic slags.

Ground Mineral Phosphate.—The imported mineral phosphates have proved useful phosphatic fertilizers on acid soils, particularly in regions of high rainfall, but they are of very doubtful value on neutral or well-limed soils. They provide the cheapest source of fertilizer P_2O_5 where the conditions are suitable for their use. The fineness of grinding necessary for maximum results has not been the subject of much investigation, but it is generally assumed that 85 to 90 per cent. passing the 100-mesh sieve is desirable.

Organic Phosphates.—Ground bones, bone dust and bone ash were the only phosphate fertilizers until J. B. Lawes was granted a patent for the manufacture of superphosphate in 1842. Bone products continued to be in demand and considerable quantities were imported to supplement the home production, but their contribution to the total phosphate supply steadily decreased. Raw bones contain fat, protein material and calcium phosphate. When the bones are fat-extracted the ground residue is known as "Bone Meal." When both fat and protein have been extracted, as in the manufacture of gelatine and glue, the residue can be more finely ground and is known as "Steamed Bone Flour." The phosphate in the latter is fairly quickly available in the soil, but raw bones and bone meal are much slower acting. The small organic nitrogen content in the bone meal is highly valued and leads to a much higher price per ton than for steamed bone flour.

Consumption of Phosphatic Fertilizers.—Before 1939 the agricultural consumption of fertilizer P_2O_5 in all forms was less than 200,000 tons per annum, but considerably increased quantities were made available during the war years.

The following table gives the estimated agricultural consumption in the United Kingdom for several post-war years and shows that this increased consumption had been maintained.

Agricultural Consumption of Fertilizer P_2O_5

Year	P_2O_5 Consumption (Thousand Tons)
1938-39	170
1944-45	345
1945-46	364
1946-47	359
1947-48 *	366

* Provisional Data.

Phosphatic fertilizer materials can be divided into four groups:

(1) Material containing water-soluble phosphate, e.g. superphosphate and ammonium phosphate; (2) basic slag, containing citric-soluble phosphate; (3) ground mineral phosphates, and (4) organic phosphates.

The contribution made by each of these groups to the estimated consumption of 366,000 tons P_2O_5 in 1947-48 was as follows:

Water-soluble phosphates	63%
Basic Slags	20%
Ground Mineral Phosphates	13%
Organic Phosphates	4%

The pre-1939 consumption represented an average of about 0·22 cwt. P_2O_5 per acre of arable land, while in 1946-47 this had increased to 0·38 cwt. per acre.

Potassic Fertilizers. *Muriate of Potash.*—The pre-war grade of muriate generally contained about 50 per cent. K_2O and was obtained from the Stassfurt and Alsace salt deposits. During the war years the alternative sources of supply in Spain and Palestine provided a rather higher grade analysing 60 per cent. K_2O which corresponds to about 95 per cent. potassium chloride. When importations were resumed after the war from Germany and France, the 50 per cent. grade was again obtained, and also a considerable quantity of a lower grade with an analysis of 40 per cent. K_2O. This latter is the material generally known as "40 per cent. Potash Manure Salts." In all the grades, the potassium is present as potassium chloride, and the impurities consist of common salt (sodium chloride) with smaller amounts of magnesium salts. There is no significant difference in the fertilizer value of these chloride salts per unit of K_2O, provided the extra sodium chloride in the lower grades is not undesirable. For certain crops, such as sugar beet and mangolds, the additional sodium may be a definite advantage, but for others, particularly where heavy rates of application are given, the sodium or the chloride may sometimes affect the quality of the produce. This appears to be the case, for instance, with potatoes in some soils and for heavily-fertilized glasshouse crops.

Sulphate of Potash.—Before 1939, approximately 25 per cent. of fertilizer potash was provided in the form of sulphate of potash, the most common grade analysing at 48 per cent. K_2O, corresponding to about 90 per cent. pure potassium sulphate. Sulphate of potash will always be dearer per unit of K_2O than the chloride salts, due to the extra processing costs. Although sulphate of potash may be preferable in some cases owing to its effect on the quality of the produce, its use is only justified if the extra quality factor has a market value. The post-war schemes of fixed and guaranteed prices, however desirable and necessary they may be, have the disadvantage that quantity counts for more than quality, and there is no economic inducement to market the highest quality produce.

Consumption of Potassic Fertilizers.—For a number of years prior to 1938, the consumption of fertilizer K_2O in Great Britain was about 75,000 tons per annum. Due to the cessation of the German supplies on the outbreak of war, potash was in very short supply until alternative sources could be arranged and the war-time rationing schemes, based on crop priorities, placed a more severe restriction on the use of potash than on either nitrogren or phosphate. The estimated post-war consumption, for several years up to 1948, is given below.

Agricultural Consumption of Fertilizer K_2O

Fertilizer Year	Consumption of K_2O (Thousand Tons)
1938-39	75
1944-45	116
1945-46	116
1946-47	125
1947-48	approx. 200

The increase in consumption after 1946 was due to the resumption of imports from Germany and France, and brought the level of consumption more into line with those for nitrogen and phosphates.

The amount of fertilizer K_2O used in Britain in 1938-39 was equivalent to 0·12 cwt. K_2O per acre of arable land, while the amount in 1946-47 was equivalent to 0·13 cwt. K_2O per arable acre. Before the war approximately as much K_2O was imported in animal feeding-stuffs as in the form of fertilizer salts, and a part, probably something over 50 per cent., would find its way on to the arable land of Britain in the form of farmyard manure. The increase in fertilizer consumption was probably less than sufficient, therefore, to counterbalance the decrease arising from the lower feeding-stuffs imports and to provide something for the additional acreage of arable land.

MIXED OR "COMPOUND" FERTILIZERS

Fertilizers are used either as top-dressings to growing crops or as seed-bed or pre-planting dressings during the preparation of the land. In the first case, a single plant food is generally given, e.g. nitrogen or phosphate, while in the second case most crops are given a mixture of plant foods containing two or all of the three food elements. Where mixtures of fertilizers are required, the farmer can purchase the straight fertilizers and make his own compound mixture on the farm, or purchase a ready-mixed "compound" fertilizer at a slightly higher cost. The use of manufactured compounds has steadily increased and more than half the total amount of fertilizers used in the United Kingdom in 1947 were supplied in the form of

factory-mixed compounds. These compounds have the advantage of uniformity of composition and they save the labour of hand-mixing on the farm. The production of compound fertilizers in granular form has made application in the field much easier, particularly with fertilizer distributors, and it seems probable that the use of factory-mixed compounds will continue to increase. The relative costs of straight and compound fertilizers are referred to later under "Valuation of Fertilizers."

An infinite number of different compounds can be mixed from the several kinds of straight fertilizers, and before 1939, manufacturers' lists contained a bewildering variety of types. Under the provisions of the Fertilizers and Feeding Stuffs Act, the manufacturer must state the composition of both straight and compound fertilizers in the terms defined in the Act. For compounds, the Statutory Statement must give the percentages of (1) total nitrogen (N), (2) soluble phosphoric acid (P_2O_5), (3) insoluble phosphoric acid (P_2O_5), and (4) total potash (K_2O). Soluble P_2O_5 is defined as P_2O_5 soluble in water under prescribed conditions. The Statutory Statement gives some essential information on the composition of the compound, but it says nothing about several important points. For instance, there is no indication whether the nitrogen is obtained from sulphate of ammonia, from nitrate of soda or from organic materials; soluble P_2O_5 may be derived from superphosphate or from ammonium phosphate; insoluble P_2O_5 from ground mineral phosphate or from steamed bone flour; potash from muriate or sulphate of potash. A statement of the ingredients of the compound fertilizer would provide, in conjunction with the information given in the Statutory Statement, a reasonably complete description of the compound fertilizer which would permit a true comparison to be made between different products.

The 1939-45 war period and its fertilizer rationing schemes led to a great reduction in the number of compound fertilizers on the market and it also introduced several "standard" compounds for which the composition was fixed in terms of N, P_2O_5, and K_2O, and which manufacturers marketed under the designation "National Compounds," under agreement with the Ministry of Agriculture and Fisheries. Just how many compounds are necessary to cover the needs of all the crops and soils in the United Kingdom is, to some extent, a matter of opinion, but there is no doubt that the number required is small compared with the number of pre-war compounds on offer. The number and composition of the National Compounds specified during the rationing period were chosen in the light of the existing supply position, and an extended range, including a wider variation in composition, would be of more general use under normal conditions of supply. Standardized compounds of this kind offer several advantages to the farmer and to advisory officers who have to help him to choose the fertilizers appropriate to his conditions. The compound manufacturer loses a certain amount of individuality, but must stand to gain much more from the increased use of compounds.

The range of national compound fertilizers during the season 1947-48 is given in the table below which includes a statement of the prescribed analyses and of the approximate ratio of plant foods in the compounds.

National Compound Fertilizers 1947-48.

National Compound	Analysis					Plant Food Ratio		
	% N	% P_2O_5			% K_2O	N	P_2O_5	K_2O
		Sol.	Insol.	Total				
No. 1	7	6·5	0·5	7·0	10·5	1	1	1·5
No. 2	9	6·75	0·75	7·5	4·5	1	0·8	0·5
No. 3	6	11·0	1·0	12·0	—	1	2	—
No. 4	4	13·75	1·25	15·0	—	1	4	—

When first introduced, No. 1 compound was recommended for potatoes, No. 2 for sugar beet, mangolds and market garden crops, No. 3 for other roots, and No. 4 for grassland and cereal crops in high rainfall districts. These different compounds, however, should not be associated too closely with individual crops since each is suitable for several crops under different soil conditions.

The composition of the National Compounds was specified on the assumption that they would be compounded from the ordinary range of straight fertilizers, i.e. from sulphate of ammonia, superphosphate, and muriate of potash. It is, of course, quite possible to prepare comparable compounds from more concentrated straight fertilizers, e.g. from ammonium phosphate or from triple superphosphate. The actual analysis of the compound is, therefore, not so important as the ratio of plant food elements it contains. For example, a compound with the analysis 10 per cent. N, 10 per cent. P_2O_5, 15 per cent. K_2O would be equivalent to National Compound No. 1, although, because of its higher concentration, 7 cwt. per acre would be equal in total plant food supply to 10 cwt. per acre of No. 1 compound. The two fertilizers would be equivalent, at the appropriate rates per acre, because they contain the same ratio of plant food elements. If it were desired to specify a range of national or standard compounds which would include fertilizers of different concentrations, it might be preferable to specify them in terms of plant food ratios rather than by analysis.

Concentrated Compound Fertilizers.—The only range of concentrated compound fertilizers currently on the market in Britain is that manufactured by one large commercial firm which utilizes mono-ammonium phosphate as a base for compounding with sulphate of ammonia and potassium salts. When first introduced in 1931, the range included six

fertilizers containing N, P_2O_5, and K_2O, and four containing only N and P_2O_5. The post-war range has consisted of the following three compounds:

Concentrated Compound	Analysis					Plant Food Ratios		
	% N	% P_2O_5			% K_2O	N	P_2O_5	K_2O
		Sol.	Insol.	Total				
No. 1	12·0	11·9	0·3	12	15	1	1	1·25
No. 2	14·0	16·3	0·2	16·5	10	1	1·2	0·7
N.P. Type A ..	13·8	41·4	0·9	42·3	—	1	3	—

The higher concentration of these fertilizers is an advantage when heavy dressings of plant food elements are applied per acre, but for low rates of application the small weight required per acre may make distribution rather more difficult. They do not contain any calcium sulphate, which is present in ordinary mixtures based on superphosphate, but, except on very acid soils, they have been equally as effective as ordinary compounds.

THE APPLICATION AND PLACEMENT OF FERTILIZERS

Methods of Application.—In the earliest days of the use of chemical fertilizers they were applied by hand, being broadcast over the soil surface after preparing the land for sowing. It was usual to follow with the harrow and thus mix the fertilizer fairly evenly through the top few inches of soil. In the course of time broadcasting machines, sometimes called "fertilizer distributors" and sometimes "fertilizer drills," were developed, and came into general use. These machines were designed to spread a powder fertilizer as evenly as possible and at a controllable rate, over the surface soil. The various manufacturers of fertilizer drills employed different types of discharge mechanism in their machines, such as revolving brushes, star wheels and reciprocating perforated plates. With the range in density and physical conditions of the wide variety of fertilizers it is obviously difficult for the rate of spread to be standardized and in practice it is necessary to find by experience the correct setting of the gears or other form of control to give the desired rate of spread with any one type of fertilizer. Most distributors give a reasonable range of spreading rates, generally between about 1 and 10 cwt. per acre, which is sufficient for most practical purposes. Although primarily designed to handle powder fertilizer most makes spread satisfactorily the more recently developed granular types of fertilizer.

After distribution it is customary for the fertilizer to be harrowed into the top soil before seed sowing, at any rate for those crops that are sown on the flat. For potatoes, the fertilizer is usually broadcast over the ridges before planting and splitting back, but some farmers prefer to run chain harrows over the ridges after applying the fertilizer to avoid too close

contact between the setts and the fertilizer. The application of top dressings of fertilizer to grassland is made either by hand or by distributor, and it may or may not be followed by harrowing.

All these customary methods of application are intended to distribute the fertilizer uniformly throughout the top few inches of soil and it was assumed that this was the most satisfactory procedure. However, there were obvious possibilities of labour saving if the two operations of fertilizer distribution and seed sowing could be accomplished at the same time. This seemed to be particularly the case with cereal crops where the quantity of fertilizer to be spread was not very great. The first attempts at combining these two operations were, in fact, made before the discovery of chemical fertilizers, but drills designed to sow both fertilizer and seed in one operation were only coming into more than occasional use shortly before the 1939-45 war. These combine drills carry two hoppers, one for seed and one for fertilizer, and they may be designed to sow both down the one spout or down separate spouts.

Apart from saving the labour of one operation it was soon found that the results on the crop of sowing the fertilizer more or less in contact with the seed were frequently much better than from the broadcast application. Experiments to compare the two methods were started in this country in 1932, but a larger body of evidence was accumulated during the early war years when a series of experiments all over the country was carried out by County War Committees. In one set of experiments during 1943-44 the average results from twenty experiments on autumn and spring-sown cereal crops, in which two different rates of superphosphate (or the equivalent amount of triple superphosphate) were applied broadcast and combine drilled were as follows:

The Combine Drilling of Superphosphate.

	Cwts. grain per acre	
	Broadcast	Combine drilled
1½ cwt. per acre superphosphate ..	16·4	18·3
3 cwt. per acre superphosphate ..	18·4	20·0
No superphosphate	14·0	

The increase in yield obtained from 3 cwt. per acre superphosphate broadcast was 4·4 cwt. grain and from the same quantity drilled 6 cwt. The advantage of combine drilling over broadcasting was such that the same increase in yield was obtained from the 1½ cwt. superphosphate drilled as from 3 cwt. broadcast.

Even more substantial advantage has been reported for the combine drilling of a complete fertilizer with oats and barley. A. H. Lewis gives the

result of sixteen Jealott's Hill experiments where the average increase in yield from combine drilling was 8 cwt. grain per acre compared with 4 cwt. grain for the broadcast application.

Some remarkable responses to potash fertilizer have been obtained in Berkshire on soils on the chalk downs. In six trials with barley in 1945 the Reading experimenters found that potash broadcast, even at 1 cwt. of muriate of potash per acre, was not very effective, but that when combine drilled the response was more substantial for both 0·5 and 1 cwt. muriate per acre when applied with a basal dressing of nitrogen and phosphates. Their yield data were as follows:

The Combine Drilling of Potash.

Fertilizer	Cwt. grain per acre	
	Broadcast	Combine drilled
N.P.*	10·8	11·6
N.P. + ½ cwt. Muriate of Potash ..	15·4	20·0
N.P. + 1 cwt. Muriate of Potash ..	15·5	21·1

* N.P. = nitrogen and phosphate.

The above results for the effect of combine drilling fertilizers with the seed of cereal crops, either winter or spring sown, illustrates the substantial benefit which can be obtained from combine drilling the fertilizer with the seed. The advantage is not, however, constant from year to year, but depends, to some extent, on the seasonal growth conditions, and it also varies quite markedly with soil conditions. In general, where the soil is very deficient in phosphates or in potash, combine drilling is particularly valuable. On fertile soils, where the response to fertilizer is only moderate, there is frequently no significant advantage to be gained from the practice.

Fertilizer Placement.—The term "fertilizer placement" is now used to describe any method of controlled distribution which localises the fertilizer in some chosen zone of soil in relation to the seed. The combined seed and fertilizer drill provides one example of "placement" in which the seed and fertilizer are placed more or less in contact in rows in the soil. Much experimental work has been undertaken, particularly in the United States, since about 1930, on the value of placing fertilizer in definite positions either below or to the side of many row-planted crops. In American farming practice several crops such as cotton and maize, and even root crops such as potatoes and sugar beet, are planted in rows of up to 3 feet in width. With this wide spacing it is to be expected that, if broadcast over the surface, some of the fertilizer would be so far removed from the plant roots as not to be of much value, particularly in the early part of the growing season. When the fertilizer is concentrated nearer the rows it is found

that the germination of many plants is seriously affected, especially in a dry season and with high rates of application of soluble compounds. The problem was tackled in a comprehensive manner by a Research Committee comprising members from the agricultural colleges and research stations, soil scientists, machinery and fertilizer manufacturers. The work carried out by this committee has resulted in the commercial production of new types of fertilizer drills designed to place the fertilizer in bands close to, and generally to the side of, the seed. The method is now known as "side-band" placement and the fertilizer bands are generally spaced $1\frac{1}{2}$ to 2 inches on either side of the seed and below the seed level. There is no particular spacing distance which is ideal for all crops, and the exact place of the fertilizer bands in the soil must be decided according to the crop and soil and climatic conditions.

In this country a limited number of experiments have been carried out on "side-band" placement of fertilizers for root crops, using specially constructed experimental drills. The results so far have not shown any consistent superiority for this technique and it seems rather unlikely that it will ever attain the degree of popularity it has achieved in America. For sugar beet, mangolds, swedes and turnips, the method has sometimes given improved yields, with the added advantages of reduced weed growth, earlier horse-hoeing and singling. As with the combine drilling of cereals, the advantage of the method for root crops has been mainly on soils markedly deficient in one or more nutrient, especially phosphate. The sowing of 2 to 3 cwt. per acre of superphosphate in contact with the seed of swedes, turnips and kale has been practised for many years in parts of Wiltshire and Dorset, but it could only be recommended on seriously phosphate-deficient soils. In general, the seeds of root crops are especially sensitive to contact with fertilizer and poor and patchy stands may easily result.

Fertilizer placement can be said to be established in Great Britain as better than broadcasting as far as the combine drilling of moderate amounts of fertilizer—probably up to 3 to 4 cwt. per acre—for cereals is concerned. Its development for root crops and for potatoes must depend on further research and practical experience. For cereals it offers a variety of advantages, some of which will be of more importance in particular cases than others. In addition to a saving in labour and increase in yield from a given amount of fertilizer it may provide better establishment and early growth, a reduction in weed growth, earlier ripening and increased resistance to wireworm attack. All these latter factors must, themselves, lead to higher yields and to a more profitable return from the expenditure on the cost of fertilizer.

FERTILIZERS AND CROPS

The actual requirements of any field for manure or fertilizer depends on very many factors. The soil type, the previous cropping and manuring,

the climatic conditions during the growing season and the kind of crop being grown are all of importance in determining just what manurial treatment is needed. The particular requirements of crops, soils and localities can only be determined from a widespread series of planned co-ordinated field experiments, but unfortunately, very few such series of experiments have been carried out over the country as a whole, that on sugar beet being a notable exception.

In the absence of the results of such planned experiments the only alternative is to evaluate the general effect of fertilizers on different crops from an analysis of all the available field experiment evidence. This, however, is only possible if the results of all the unco-ordinated experiments can be reduced to some standard basis which allows average data to be calculated. E. M. Crowther and F. Yates[1] accomplished this by assuming the general validity of a formula which defined the response of crops to the main plant foods N, P_2O_5 and K_2O. This expression of the Law of Diminishing Returns assumes that there is a limiting or maximum response to each plant food in any particular case, and that this maximum response is obtained from a constant amount of fertilizer. The response to dressings less than this maximum amount was shown to be in accordance with the following formula:

$$y = Yo + d\,(1 - 10^{-kx})$$

where y = the yield obtained with x cwt. per acre of plant food.
Yo = the yield obtained with no addition of fertilizer.
d = the limiting, or maximum, response to that plant food.
and k = a constant for each plant food.

By using a response curve of this kind Crowther and Yates were able to calculate the yield response which would be obtained from an empirically chosen standard rate of dressing and to express the response to other rates of dressing relative to this standard rate. This then allowed them to reduce the results of a miscellaneous collection of field experiments to terms of the response to the standard rate of dressing, and thus to average the results from all these experiments and obtain mean values for the crop response to fertilizers.

The empirical "standard" rates of dressing adopted by Crowther and Yates were N = 0·25 cwt. per acre, P_2O_5 = 0·5 cwt. per acre, and K_2O = 0·5 cwt. per acre. If the response in yield to these rates is taken as equal to 1·0 the response to other rates relative to those standards is as given on page 70 (Table 11 in their paper).

In any field experiment which measures the response of a particular crop to a given rate of dressing of N, P_2O_5 or K_2O the observed response can be reduced to "standard" by dividing by the value of the relative response corresponding to that rate of dressing. In this way, the results of many field experiments can be brought to the same basis and thus provide data which

[1] E. M. Crowther and F. Yates. "Fertilizer Policy in Wartime. The fertilizer requirements of arable crops." *Imp. Journal Exp. Agric.*, 9, 1941 (77-97).

can be used to show the average response of different crops to these fertilizer elements. It should be noted that the "standard" rates of dressing were arbitrarily chosen and they have no direct bearing on the question of the optimal rates of dressing for different crops, although they were chosen as being somewhere round about average. The average responses of different

Standard Response Curves for N, P_2O_5 and K_2O.

Nitrogen ($k_n = 1{\cdot}1$)		Phosphoric Acid and Potash (k_p and $k_k = 0{\cdot}8$)	
Cwt. N. per acre	Relative Response	Cwt. P_2O_5 or K_2O per acre	Relative Response
0·1	0·48	0·2	0·51
0·2	0·85	0·4	0·87
0·25	1·00	0·5	1·00
0·3	1·14	0·6	1·11
0·4	1·36	0·8	1·28
0·5	1·53	1·0	1·40
0·6	1·67	1·2	1·48
0·7	1·77	1·4	1·54
0·8	1·85	1·6	1·58
0·9	1·91	1·8	1·60
1·0	1·96	2·0	1·62

crops to the standard rates do indicate, however, the relative importance of N, P_2O_5 and K_2O for each crop, and they also show how the best economic return can be obtained from a limited supply of fertilizers, for which purpose, in fact, Crowther and Yates undertook their survey.

The table on page 71 shows the average response to fertilizer treatment of different crops grown in Great Britain and has been prepared from the more detailed data given in Crowther and Yates' paper. Their original tables show that the average responses in this country are, in general, in line with those obtained from a very much larger number of experiments in Ireland, Denmark, South Sweden and East Prussia.

Some of the general conclusions which can be drawn from the complete data presented in this paper are that:

(*a*) Nitrogenous fertilizers give practically the same response in crop yield in the presence as in the absence of a dressing of dung.

(*b*) Dung reduces the response of all crops to phosphate and potash to a marked extent. Crowther and Yates state that a 10-ton dressing of average quality dung reduces the response to phosphates by about one-half, and to potash by about two-thirds.

(*c*) This effect of dung means that the fertilizer needs can be reduced

by about 2 cwt. per acre superphosphate and 1 cwt. per acre muriate of potash when a 10-ton dressing is applied.

(*d*) The percentage response to nitrogen is greatest for cereals, being about 20 per cent. for a dressing equivalent to 1·2 cwt. sulphate of ammonia. Potatoes, mangolds, swedes and sugar beet show responses ranging from about 12 per cent. to about 9 per cent. in that order.

(*e*) The response to phosphate is much greater for swedes than for the other root crops, which showed about half the response (in weight) for potatoes and mangolds, and still less for sugar beet. Cereals showed only small response to phosphate, except in the wetter districts.

(*f*) The response to potash was greatest for potatoes, followed by swedes and mangolds. Sugar beet gave only a small response, either in terms of roots and tops or of sugar per acre.

(*g*) The response to nitrogen does not vary very markedly in different parts of the country, but the response to phosphate is decidedly higher in regions of high rainfall. The response to potash is generally higher in the north than in the south, but the difference is not great.

Response of different crops to Fertilizer Treatment.
(Great Britain.)

	Mean Response (tons per acre)				Mean Response (cwt. grain per acre)		
	Swedes	Man-golds	Sugar Beet	Potatoes	Wheat	Barley	Oats
Nitrogen (0·25 cwt. N)							
(*a*) with dung	2·3	2·6	0·92	0·86	—	—	—
(*b*) without dung	2·2	3·1	0·88	1·07	3·4	3·7	3·4
Phosphoric acid (0·50 cwt. P_2O_5)							
(*a*) with dung	2·3	1·0	0·66	0·55	—	—	—
(*b*) without dung	4·4	2·4	0·41	0·84	0·3*	0·6	1·5
Potash (0·50 cwt. K_2O)							
(*a*) with dung	0·9	1·7	0·17	0·55	—	—	—
(*b*) without dung	2·3	1·9	0·44	1·23	2·3*	0·4	0·8

* Data for a small number of experiments only.

The effect of fertilizers can also be evaluated in terms of the extra starch equivalent or protein equivalent produced per acre. The following data have been calculated from Crowther and Yates' tables of average responses to the "standard" rates of dressing, the root crops being assumed to be grown with dung, and cereals without dung.

From the point of view of their ability to convert plant food into feeding-stuffs, measured by starch equivalent value, it will be seen that mangolds, potatoes and swedes are more efficient users of nitrogen than sugar beet or cereals. For phosphoric acid, swedes are much more responsive in starch production than any other crop, followed by potatoes, mangolds and sugar beet, while the cereals show a much lower return. In the case of potash,

Response to 'standard' dressings in cwt. per acre.
Starch Equivalent.

	Swedes	Mangolds	Sugar Beet	Potatoes	Cereals
Nitrogen (0·25 cwt. per acre)	3·1	3·5	2·7	3·2	2·4
Phosphoric Acid (0·5 cwt. per acre)					
S. and E. England	1·8	0·9	0·9	1·1	0·5
W. Mid. and N. England	2·6	1·3	1·2	1·8	0·7
S.W. England, Wales and Scotland	4·4	2·2	2·1	2·8	1·1
Potash (0·5 cwt. per acre)	1·5	2·1	0·8	2·0	0·5

mangolds and potatoes show the greatest efficiency while swedes occupy an intermediate place between these and sugar beet and the cereals. Data of this kind give, of course, only the broad, general average effect of fertilizers and are of more use in formulating a general fertilizer policy for the country as a whole, particularly in times of shortage of supply, than in deciding a fertilizer programme for any one form. The value to the farmer of the extra yield given by a fertilizer dressing depends on the use he makes of the crop, and the cash value of that crop if he sells it off the farm. In the above case, the figures for sugar beet do not take into account the extra feeding-stuffs produced from the tops, and if these are fed, due allowance should be made for this in comparing, say, the returns from mangolds and sugar beet.

The above data for average responses to fertilizers are for root crops grown with dung, and can be approximately doubled in the absence of dung in the case of phosphoric acid and potash, and increased by 10 per cent. for nitrogen.

Root crops are particularly responsive to dressings of dung, and Crowther and Yates give data for average responses from which the following table of increased yields of starch equivalents has been calculated.

The Response of Root Crops to Dung.

	Increase in yield from 10 tons of dung per acre		
	Cwt. Starch Equivalent per acre		
	Swedes	Mangolds	Potatoes
(*a*) Fertilizers absent:			
S.E. England	6·7	5·5	7·1
W. Mid. and N. England	8·9	7·2	10·0
S.W. England, Wales and Scotland	10·4	12·2	12·1
Great Britain	9·3	10·1	10·0
(*b*) Fertilizers present: Great Britain	3·8	3·8	5·0

Potatoes show the largest average response to dung measured in terms of starch equivalent produced, although, in the absence of fertilizers, mangolds give the same response in the wetter parts of the country. Since the cash value per unit of starch equivalent is much higher for potatoes than for swedes or mangolds, the above data show that potatoes give the best financial returns for a dressing of dung. If potatoes are grown as one of the main cash crops on the farm they should, therefore, be given first priority for dung, particularly when supplies are limited, as they generally are on cash-cropping farms.

Optimal Rate of Dressing.—The yield response curves used by Crowther and Yates can also be used to calculate the "optimal" or most profitable rates of fertilizer dressing for any given value of produce and cost of fertilizer. The absolute maximum yield which a field is capable of giving

Effect of Superphosphate on Potatoes.

Dressing cwts. per acre		Increased crop tons per acre		Gross profit shillings per acre	
P_2O_5	Superphosphate	Without dung	With dung	Without dung	With dung
0·4	2·2	0·87	0·44	139	63
0·8	4·4	1·28	0·64	198	86
1·2	6·7	1·48	0·74	220	91
1·6	8·9	1·58	0·79	225	86
2·0	11·1	1·62	0·81	219	78

is seldom the most profitable since the returns from the last hundredweight of fertilizer may not pay for the cost of that fertilizer. E. M. Crowther (*J. Min. Agric.*, 54, 491-500) gives some examples based on the prices ruling in 1948. In this article he illustrates the use of the fertilizer response curve in showing the effect of superphosphate on potatoes. In the previous table "gross profit" is the difference between cost of the fertilizer dressing and the value of the average increase in yield which would be obtained.

At the current prices the most profitable rate of dressing of superphosphate was about 9 cwt. per acre where dung was not used, and about 7 cwt. per acre where it was. These are admittedly high rates, and it will be noted that there is a fairly wide range of dressing which gives practically the same margin of gross profit. It will generally be sound policy to give dressings less than these "optimal" dressings, and in the above case 6 to 7 cwt. of superphosphate per acre without dung and 4 to 5 cwt. per acre with dung would be reasonable dressings in practice under average conditions on good potato land.

Crowther also illustrates in the same article the relative fertilizer requirements of different crops on the basis of 1948 prices, reproduced below:

Most Profitable Dressings at 1948 prices.

	Cwt. plant food per acre		
	Potatoes	Sugar Beet	Cereals
Without dung			
N	1·2	1·0	(0·9)
P_2O_5	1·5	1·1	0·4
K_2O	1·8	1·2	0·4
With dung			
N	1·1	0·9	(0·9)
P_2O_5	1·2	0·8	Nil
K_2O	1·2	0·6	Nil

The table above shows that cereals do not require much phosphate or potash under average soil conditions and especially where dung has been given. On soils known to be deficient in either phosphate or potash or where the cereal has been undersown, then these plant foods will be required in greater amounts. Although the most profitable dressing of nitrogen for cereals is very high, the need to avoid lodging sets a practical maximum, which would be about 0·6 cwt. N. per acre (3 cwt. sulphate of ammonia) in the drier parts of the country, and about 0·3 cwt. N. (1½ cwt. sulphate of ammonia) in the areas of higher rainfall. More detailed tables of optimal rates of dressing are given in Crowther and Yates' original paper.

Although the method by which the dresssings were calculated may seem to be somewhat theoretical and involve the use of mathematical equations, it is important to remember that the basic data were the results of fertilizer trials in the field, and that they provide, therefore, a sound practical guide to the proper use of fertilizers for different crops under average conditions. The most important factor which must be taken into account in translating these results into practice is the special needs of different types of soil, and in this connection, the farmer's own experience is the best guide.

SURVEYS OF FERTILIZER PRACTICE

During the period 1941-44, information on the use of farmyard manure and fertilizers under war-time conditions was obtained by a survey of a random selection of farms of different sizes in a number of counties in England and Wales. This survey, which was carried out jointly by the advisory chemists of the National Agricultural Advisory Service and the staff of the Rothamsted Experimental Station, provided valuable data on the manuring of crops in various parts of the country.. Results are not available for every county but those included in the survey gave examples of most of the different systems of farming under a variety of soil and climatic conditions. The separate county reports, published by the Ministry of Agriculture and Fisheries, contain a mass of detailed information from which the following summary has been prepared from the reports for a selection of the surveyed counties.

In the table on the next page the average production of farmyard manure in a number of districts in England and Wales is given as the tons of manure produced per acre of crops and grass. This figure is, of course, related to the number of cattle carried on the average farm in the district, and is an approximate measure of the contribution of farmyard manure to the maintenance of soil fertility in these areas. It should be noted, however, that it does not include any allowance for the dung dropped on grazing land or the manure produced by sheep.

The amount of manure produced per acre of crops and grass ranged from over 3 tons per acre in the upland areas of the West Riding of Yorkshire to about 10 cwt. per acre in the Cotswold district of Gloucestershire. In the mainly stock-farming counties of the north and south-west the production averaged about 2 tons per acre, and since these districts had the smallest proportion of land under arable crops, the amount of manure which could have been given to the arable land was very high, in some cases more than 10 tons per acre. In these grassland districts, however, the practice was to use a considerable proportion of the total production as dressings on grassland, mainly on those fields to be cut for hay. More than half the manure was thus used in the upland parts of the West Riding and in Somerset, particularly in the dairying districts, while about one-third went on to grassland in the upland parts of Cumberland, Merionethshire,

Gloucestershire (including the Cotswolds) and Warwickshire. The mainly arable-farming counties of the south and south-east, where the average production of manure was one ton, or less, per acre of crops and grass, used very little on either permanent or temporary grassland Most of the available supply was used on root crops although in the heavy soil counties (e.g. S. Essex) about one-third was used on corn and pulse crops, particularly wheat and beans.

The Production and Over-all Average Application of Farmyard Manure.

County	Farmyard Manure production. Tons per acre arable and grass	Over-all average application of Manure—tons per acre				
		Arable land				Permanent Grassland
		Corn and Pulses	Roots and Green Crops	Temporary Grassland	All Arable	
Yorks — West Riding						
(1) Western Upland Areas ..	3·2	1·6	12·6	3·7	3·6	2·9
(2) Eastern Arable Areas ..	2·4	0·1	10·1	0·7	3·0	0·1
Cumberland						
(1) Uplands ..	2·0	0·5	11·1	2·5	2·9	1·2
(2) Lowlands ..	2·3	0·5	14·1	1·8	3·0	0·7
Merionethshire ..	1·6	1·2	8·1	1·0	2·0	1·2
Somerset						
(1) Main Dairy Grasslands ..	1·8	0·5	9·8	—	1·2	2·0
(2) Mixed Farming Areas ..	1·1	0·7	8·4	—	2·1	1·1
Warwickshire ..	0·9	0·4	5·5	0·3	1·0	0·7
Gloucestershire						
(1) Cotswolds ..	0·5	0·9	5·3	0·1	0·6	0·3
(2) North and West	1·1	0·7	8·6	—	2·0	0·7
Essex (South) ..	0·7	0·8	5·9	—	1·1	0·3
Hertfordshire						
(1) Eastern District	0·9	0·4	5·9	0·2	1·1	0·2
(2) Western District	0·9	0·4	9·4	0·2	1·4	—
Lincolnshire						
(1) Holland ..	1·5	0·2	3·7	—	1·7	0·2
(2) Lindsey ..	1·4	1·5	3·8	0·1	1·8	0·4
Isle of Ely ..	0·9	0·2	2·1	0·1	0·9	0·2

The average dressings of manure varied considerably in different districts, as did also the proportion of fields carrying any one crop which received a dressing. The average applications taken over the total crop acreages, including those fields not receiving any manure, are also given in the table on page 76. This "over-all average" quantity gives the best measure of the importance of farmyard manure in maintaining soil fertility on the arable land in different districts.

In the stock-farming areas the amount of manure used on arable land was equivalent to an annual dressing of about 3 tons per acre, while the mixed farming and arable farming counties of Warwickshire, South Essex, Hertfordshire and the Isle of Ely, used about 1 ton per acre of arable land. Both the Holland and Lindsey divisions of Lincolnshire used about 1¾ tons per acre, which is rather more than the average for Somerset, although that county had a much larger proportion of manure on the basis of arable land acreage.

The root and green crops received, as would be expected, the heaviest over-all applications of manure, and in all these counties, except Lincolnshire and the Isle of Ely where the acreages of roots were large, land under these crops received an average dressing of over 5 tons and generally more than 8 tons per acre. In the Lindsey division of Lincolnshire the corn and pulse acreage received almost as much manure as in the upland areas of the West Riding and considerably more than in any of the other districts or counties. With only one exception, temporary grassland was given less manure than permanent grassland, and in the majority of cases it was applied to fields to be mown for hay.

Since most arable land receives plant food from both manure and fertilizers, if not every year, at some time during the rotation, an estimate has been made of the total plant food supplied per annum on the basis of the average amounts of manure and fertilizer stated in the Survey Reports. The plant food value of farmyard manure has been taken as 0·06 cwt. of nitrogen, 0·04 cwt. phosphoric acid and 0·08 cwt. of potash per ton which corresponds to 60 per cent. of the total nitrogen and 80 per cent. of the total phosphate and potash in average quality manure. This is higher than the fertilizer value of manure to the first crop but it makes some allowance for the residual value of the manure to succeeding crops. Such an estimate must be subject to considerable error, but it probably gives a fair approximation on the average. The table on page 78 gives the amounts of plant food (N, P_2O_5, and K_2O) from fertilizers and the estimated contribution from manure, together with the total plant food units in cwt. per acre, for the above series of counties.

The lowest amounts of plant food applied per arable acre were found in some of the dairying and stock-rearing districts, and the highest in the intensively arable acres such as the fens of East Anglia. There was a much wider range in amounts of nitrogen and potash used per acre than of phosphate. In the case of potash it must be remembered that the Survey was

Estimated over-all average applications of plant food on arable land.

County	Plant food—cwt. per acre									
	N			P_2O_5			K_2O			Total Plant Food Units
	Ferti-lizers	FYM	Total	Ferti-lizers	FYM	Total	Ferti-lizers	FYM	Total	
Yorks W. Riding										
(1) Western Upland Areas	·08	·22	·32	·20	·14	·34	·05	·29	·34	1·00
(2) Eastern Arable Areas	·23	·18	·41	·29	·12	·41	·22	·24	·46	1·28
Cumberland										
(1) Uplands	·06	·17	·23	·30	·12	·42	·02	·23	·25	0·90
(2) Lowlands	·08	·18	·26	·21	·12	·33	·03	·24	·27	0·86
Merionethshire	·04	·12	·16	·32	·08	·40	·02	·16	·18	0·74
Somerset										
(1) Main Dairy Grasslands	·05	·07	·12	·23	·05	·28	·01	·10	·11	0·51
(2) Mixed Farming Areas	·08	·13	·21	·19	·08	·27	·05	·17	·22	0·70
Warwickshire	·10	·06	·16	·27	·04	·31	·05	·08	·13	0·60
Gloucestershire										
(1) Cotswolds	·10	·04	·14	·40	·02	·42	·06	·05	·11	0·67
(2) North and West ..	·08	·12	·20	·34	·08	·42	·04	·16	·20	0·82
Essex (South)	·15	·07	·22	·17	·04	·21	·05	·09	·14	0·57
Hertfordshire										
(1) Eastern District ..	·23	·07	·30	·24	·04	·28	·07	·09	·16	0·74
(2) Western District ..	·16	·08	·24	·19	·06	·25	·06	·11	·17	0·66
Lincolnshire										
(1) Holland	·41	·10	·51	·38	·07	·45	·38	·14	·52	1·48
(2) Lindsey	·24	·11	·35	·34	·07	·41	·14	·14	·28	1·04
Isle of Ely	·30	·05	·35	·40	·04	·44	·35	·07	·42	1·21
Fens of East Anglia ..	·37	·08	·45	·40	·06	·46	·37	·11	·48	1·39

conducted during the period of war-time rationing, and that only those areas with a large potato acreage, such as the fens, had a substantial allocation. Taking this into account it would seem that the biggest difference between the grassland and arable areas lay in the amount of nitrogen used on the arable land. To some extent, which cannot be accurately estimated, this difference would be partly counterbalanced by the amount of nitrogen accumulated in the longer leys in the grassland districts.

In the north and west of the country, farmyard manure generally provided larger proportions of the total addition of nitrogen and potash and a smaller proportion of the phosphate. In the arable districts, and particularly in East Anglia, farmers relied mainly on fertilizers as the source of the greater part of all three plant foods. This was due not so much to the absence of manure—the average application per arable acre in the fens of East Anglia was as high as in several of the dairying and stock-rearing counties—as to the larger total amounts of plant food used per acre, which were approximately twice as much as in most of the other surveyed areas. In general, where farmyard manure was plentiful, farmers used comparatively small amounts of fertilizers, except phosphate to some extent, and the manure supplied 50 per cent. or more of the total plant food added annually to arable land. In the mainly arable areas, particularly in the fens, manure accounted for only about 20 per cent. or less of the total plant food supply. In those areas soil fertility, as far as it is related to plant food, would seem to be at a much higher level and to be more dependent on fertilizers than on manure.

The following table and the table on page 80 deal with data from all the farms in the surveyed districts, but in some cases information was also obtained which brought out the differences in fertilizer practice between large and small farms in the same area. The following data have been extracted from the Reports for the Lindsey division of Lincolnshire and for Hertfordshire.

Comparison of manuring on large and small farms.

County	Size of Farm	No. of Farms	Applied on arable land—per acre: Tons FYM	Cwt. N	Cwt. P_2O_5	Cwt. K_2O
Lindsey ..	under 50 acres	16	2·8	·24	·19	·11
(Districts 1 & 4)	over 50 acres	53	1·7	·29	·41	·20
	10 to 150 acres	13	2·3	·14	·07	·03
West Herts. ..	151 to 300 acres	19	1·3	·16	·25	·05
	over 300 acres	17	1·4	·18	·21	·09

In both counties the small farms used about 1 ton per acre more manure on the arable land and less fertilizers, particularly phosphate and potash. In West Hertfordshire the amount of plant food supplied from fertilizers

on the farms with less than 150 acres of crops and grass was about one-half of that supplied on the over 300 acres farms. This difference arose partly from the fact that the larger farms used higher rates of application, and partly because the smaller farms applied fertilizers to a smaller proportion of the total arable land each year. This was especially the case for the new arable fields ploughed out of grass during the war years, which frequently received inadequate fertilizer treatment on the smaller farms.

Fertilizer practice obviously varied quite widely between different districts due in part to difference in soils and in systems of farming, and in part to different degrees of experience and knowledge among farmers themselves. The data discussed so far referred to the over-all average use of manure and fertilizers on arable crops. The different treatment given to the one crop in various districts illustrates the difference in farmers' practice and experience more precisely than these over-all average data. From the Survey Reports the following data have been extracted for the manuring of (1) potatoes, and (2) wheat for several counties and districts.

The manuring of potatoes in different districts.

(Tons FYM, cwt. N, P_2O_5 and K_2O per acre)

County and District	Percentage of acreage receiving :				Average actual rates of application per acre			
	FYM	N	P_2O_5	K_2O	FYM	N	P_2O_5	K_2O
Lincs, Holland ..	50	100	100	100	11·2	·86	1·02	1·10
Lincs, Lindsey ..	59	98	98	99	9·1	·89	·93	1·10
Isle of Ely (peats) ..	26	96	100	95	9·3	·82	1·08	1·07
Hertfordshire—West	91	80	80	81	12·3	·52	·65	·73
Yorks—West Riding	75	95	94	95	15·6	·74	·74	1·12
Warwickshire ..	69	92	95	81	9·4	·51	·59	·77
Somerset	47	46	77	50	13·9	·37	·64	·57
Merionethshire ..	98	30	42	27	10·6	·27	·49	·36

In most districts the greater part of the potato acreage received a moderate to heavy dressing of manure, although in the Isle of Ely only about one-quarter and in Lincolnshire and Somerset about one-half was given manure. Very few fields, except in Merionethshire and Somerset, were not given phosphate, although the rate per acre varied considerably. More than 80 per cent. of fields received complete fertilizer treatment in the same two counties. The average rates of application for all three fertilizer plant foods were very much higher in Lincolnshire and the Isle of Ely peat areas than in the other counties and districts. To some extent this was balanced by a more frequent use of manure, except in the case of Somerset. The low level

of fertilizer use in Somerset and Merionethshire was no doubt due to the fact that potatoes were a comparatively new crop to most farmers in these counties at the time the survey was carried out and they had insufficient experience or knowledge of its fertilizer needs.

Farmyard manure was very seldom given to wheat except in the Lindsey division of Lincolnshire, and even in this area only 30 per cent. of the fields received a light dressing of about 8 tons per acre.

The manuring of wheat in different districts.

(Tons FYM, cwt. N, P_2O_5 and K_2O per acre)

County and District	Percentage of acreage receiving:				Average actual rates of application per acre			
	FYM	N	P_2O_5	K_2O	FYM	N	P_2O_5	K_2O
Lincs, Holland ..	—	13	—	—	—	·40	—	—
Lincs, Lindsey ..	30	57	26	3	7·9	·29	·58	·17
Essex—South ..	1	53	25	7	8·0	·28	·45	·14
Yorks—West Riding	4	55	37	3	11·4	·22	·56	·32
Glos—North and West	—	43	51	—	—	·18	·65	—
Glos—Cotswolds ..	—	33	71	3	—	·23	·68	·51
Wilts—West ..	—	29	57	10	—	·23	·48	(·44)
Warwickshire ..	2	30	36	1	8·2	·23	·75	·45
Somerset	2	16	45	—	9·6	·25	·62	—
Cumberland—Uplands	12	21	64	—	11·0	·21	·52	—

(Figure bracketed based on average of less than 10 fields.)

Very few fields were given potash in any of these areas, but wheat was not a priority crop during the war-time rationing period. The use of nitrogen and phosphate was more common but more than half the acreage received nitrogen in only three and phosphate in only four districts. Except for the comparatively small acreage in the Holland division, which received the equivalent of 2 cwt. sulphate of ammonia per acre, the rates of application of nitrogen on the fields receiving this fertilizer did not vary very widely and averaged about 1¼ cwt. of sulphate of ammonia. Where phosphate was applied the rates were fairly high and equivalent to about 3 cwt. of superphosphate per acre. When farmers used fertilizers for wheat there was less variation in rates of application than in the case of potatoes, but they more frequently used none at all.

Considerable space has been given to a summary of only a few of the aspects of fertilizer practice dealt with in the Survey Reports and a continuation of the Survey would provide valuable information on the farmers' use of fertilizers under more normal conditions of supply than existed during

the war-time years. Perfection in the use of fertilizers is unattainable, and there always will be wide variations in practice under different soil, farming and climatic conditions. The maintenance of soil fertility combined with maximum economic production means making the best use of both farmyard manure and fertilizers, and such surveys help to show where improvement can be expected on the basis of the best practice.

THE VALUATION OF FERTILIZERS

With the variety of fertilizers on the market which differ in composition and in concentration, as well as in price, it is important to be able to compare one with another on some standard basis. The most practicable method of valuation is to compare the price for different fertilizers of some definite weight of nitrogen, phosphoric acid and potash, and to take into account the different value to the farmer of soluble and insoluble compounds of phosphoric acid. The standard weight chosen is $\frac{1}{100}$th part of a ton, i.e. 22·4 lb., and this weight is called a "unit." The prices of 22·4 lb. of nitrogen, soluble and insoluble phosphoric acid and potash are called "unit prices" or "unit values."

The number of "units" of N, P_2O_5 or K_2O in a ton of fertilizer is given by the percentage of each contained in the fertilizer, since 1 per cent. of a ton was defined as the unit weight. For example, sulphate of ammonia containing 20·5 per cent. of nitrogen contains 20·5 units of nitrogen per ton. Similarly, ammonium phosphate containing 11 per cent. nitrogen and 48 per cent. phosphoric acid contains 11 units N and 48 units of P_2O_5 per ton of fertilizer.

For fertilizers such as sulphate of ammonia, superphosphate and muriate of potash, which contain only one fertilizer element, the price of the unit weight is obtained simply by dividing the price per ton by the number of units, i.e. by the percentage numbers of N, P_2O_5 or K_2O as the case may be. There is frequently some difficulty, however, in deciding what the price per ton actually is. The prices quoted in manufacturers' lists generally state the price per ton for a minimum of 6-ton lots, delivered to the buyer's nearest station. Since the farmer uses the fertilizer on his fields, and not at the railway station, the list price should be adjusted for the cost of carriage from the station to the farm. This gives what may be called the "on the farm" price.

The fertilizer may have to be stored on the farm for some time before it is carted to the field and distributed, either by hand or by fertilizer drill, so that the cost of storage and distribution should be also taken into account. Where a farmer buys "straight" fertilizers and mixes his own compound fertilizers on the farm, the labour costs of mixing and rebagging have also to be added. When the appropriate adjustments for these extra items of cost have been made, the final price can be taken as the true "in the soil" price of the fertilizer.

It may be said that some of the adjustments to the list price are unnecessary, and that may be so in certain cases. Where it is desired to compare the unit price of potash in muriate of potash and sulphate of potash, for example, it can be assumed that the cartage, handling and distribution costs per ton would be practically the same in both cases and, therefore, it would be sufficient to take the unit price calculated from the "delivered to station" price per ton in order to compare the cost of potash in the two materials.

When the appropriate price per ton has been found, the unit price of the fertilizer element can be calculated, as already stated, by dividing the price per ton by the number of per cents. of the element. For example, sulphate of ammonia may be quoted at £10 5*s*. per ton, delivered to station during March to June, in 6-ton lots, and at least this quantity is required and delivery will be taken during these months. If the sulphate of ammonia is guaranteed to contain 20·5 per cent. nitrogen, then the unit price of nitrogen is 205*s*. divided by 20·5 or 10*s*. This represents the unit price in *6-ton lots at station during March to June* and should only be compared with the unit prices of nitrogen from other fertilizers on the same basis. Unit prices should not, therefore, be considered as absolutely fixed prices, but as the prices under a given set of circumstances, and it should be recognized that these circumstances, and hence the unit prices, can vary in different cases.

To illustrate this point further we can take the case of a farmer buying 2 tons of sulphate of ammonia for delivery during October. Suppose the quoted price for 2-ton lots is £10 15*s*. delivered to station, and that it costs 7*s*. 6*d*. per ton for cartage to the farm, and that there is an early delivery rebate of 25*s*. per ton during October. The net price per ton on the farm is, therefore, £10 15*s*. plus 7*s*. 6*d*., minus 25*s*., or £9 17*s*. 6*d*. The unit price of nitrogen is now 197*s*. 6*d*. divided by 20·5, or just about 9*s*. 7½*d*. per unit for *2-ton lots delivered on the farm during October*. In the above examples purely hypothetical prices have been chosen for purposes of illustration.

When it is desired to compare the value of compound fertilizers containing two or more fertilizer elements, it is necessary, first of all, to obtain a standard unit value for each element. For this standard value, the lowest unit prices for nitrogen, soluble phosphoric acid, insoluble phosphoric acid and potash are calculated from the quoted prices of "straight" fertilizers containing only the one element, taking into account any appropriate adjustments as mentioned above.

The lowest unit prices in "straight" fertilizers are generally those calculated for:

Nitrogen in Sulphate of Ammonia;
Soluble Phosphoric Acid in Superphosphate;
Insoluble Phosphoric Acid in Ground North African Phosphate;
Potash in Potash Salts or in Muriate of Potash.

On the basis of the 1948 March to June prices for 6-ton lots delivered at station, the unit values are as follows:

Nitrogen	10*s.* 1¾*d.*, say, 10*s.* 2*d.*
Soluble P_2O_5	6*s.* 7¼*d.*, say, 6*s.* 7*d.*
Insoluble P_2O_5	4*s.* 3¼*d.*, say, 4*s.* 3*d.*
K_2O	4*s.* 7¼*d.*, say, 4*s.* 7*d.*

(K_2O: Ex ship and f.o.r. at Port. Carriage extra)

To obtain from these standard unit prices the value of a compound fertilizer, the number of units of each element is multiplied by its appropriate unit price and the products added together.

The calculation can be illustrated as follows, taking the war-time National No. 1 compound as an example. The guaranteed analysis of this compound is 7 per cent. nitrogen, 6½ per cent. soluble P_2O_5, ½ per cent. insoluble P_2O_5 and 10½ per cent. K_2O. Using the above unit prices for N, P_2O_5 and K_2O the valuation of the compound is, therefore:

7 units of Nitrogen (N)	.. @	10*s.* 2*d.*	per unit =	£3	11*s.* 2*d.*
6½ units of Soluble P_2O_5	.. @	6*s.* 7*d.*	per unit =	£2	2*s.* 9½*d.*
½ unit of Insoluble P_2O_5	.. @	4*s.* 3*d.*	per unit =		2*s.* 1½*d.*
10½ units of Potash (K_2O)	.. @	4*s.* 9*d.**	per unit =	£2	9*s* 10*d.*
			Total	£8	5*s.* 11*d.*

* Allowing for the cost of carriage from port.

The valuation calculated in this way is always lower than the manufacturers' quoted price for the compound and the difference, which may amount to about 45*s.* to 50*s.* per ton of fertilizer, represents the price paid for his mixing, storing and handling of the compound, and in some cases, for the granulation of the fertilizer, together with the profit from his manufacturing business.

It should be noted that the above valuation was made on the basis of 6-ton lots, and this may introduce a complication. If a farmer intends to use, say, 6 tons of No. 1 National Compound for 12 acres of potatoes and this is the only fertilizer he wants to order at that time, he has the choice between ordering the 6 tons or approximately 2 tons of sulphate of ammonia; 3 tons superphosphate and 1 ton muriate of potash to mix himself, into a fertiliser, with similar analysis. Unless the manufacturer or merchant is prepared to supply these three items at the 6-ton price in each case, the unit prices would need to be adjusted to allow for the increased price of the smaller quantities.

The best comparison between the prices charged for two different manufacturers' compounds is given by the difference in each case between the actual price per ton and the valuation on a unit plant food basis. In other words, by comparing the "mixing" charge for a given amount of plant food in each case. For example, it may be found that the mixing charge for a manufacturer's compound containing a total of 24½ plant fertilizer units per ton (as No. 1 National Compound) is 47*s.* per ton, while for a more concentrated compound containing 39 fertilizer units it is 57*s.* per ton. The

"mixing" cost *per unit* in the first case is 1*s.* 11*d.* and in the second 1*s.* 5½*d.* On this basis the more concentrated the compound the cheaper it is to the farmer, assuming it is equally suitable for his particular requirements.

An attempt is sometimes made to make allowance for some factors other than N, P_2O_5 and K_2O in fertilizers, such as the effect of the fertilizer on the lime status of the soil. It is undoubtedly true that certain fertilizers, e.g. sulphate of ammonia, lead to a greater loss of lime from the soil in drainage water, but the writer believes that any attempt to evaluate this in terms of the amount of lime theoretically required to counter-balance the loss due to the fertilizer is subject to considerable inaccuracy. In any such calculation, certain assumptions have to be made, and these may or may not be valid in any particular case. For example, it is frequently stated that each 1 cwt. of sulphate of ammonia increases the loss of lime by slightly over 1 cwt. of carbonate of lime. This statement is based on the assumption that *all* the sulphate part of the fertilizer combines with lime in the soil and is leached out and lost in the drainage water as calcium sulphate. This may be true in some cases, but in others it is just as possible that the crop will utilize part of the sulphate and that the net amount of calcium sulphate appearing in the drainage water will be less than that theoretically calculated. Unfortunately, we still have insufficient experimental data from drain gauge or lysimeter experiments to say with any certainty what is the average loss of lime *in practice* for those fertilizers which have an acidifying effect.

Some fertilizers, e.g. basic slag and cyanamide, contain compounds of calcium and, therefore, they can be said to have some lime value. While this lime value may be very useful in maintaining a soil in good lime condition, the rates of application are seldom heavy enough to correct any serious degree of soil acidity. Some of the low-grade basic slags, however, may be applied to grassland at rates up to 20 cwt. per acre, and at this rate the dressing will be equivalent to a light liming. The slag should not be relied on to supply all the lime needed on very sour land and adequate dressings of burnt lime or ground limestone should be given periodically in all such cases.

In general, it is probably true that the effect of fertilizers on the lime status of soils can be left out of account in assessing their value, provided it is remembered that sulphate of ammonia *tends* to increase the natural loss of lime from the soil, and basic slag *tends* to replace some of the loss. Apart from these two cases it has yet to be proved that fertilizers, used in the quantities normal in farming practice, have any significant effect on soil acidity.

DEVELOPMENTS IN FERTILIZER MATERIALS

Nitrogen Fertilizers.—The range of fertilizer materials in large-scale use in Great Britain has shown several changes during the past fifty years. The erection of nitrogen fixation plants led to an increase in the amount of sulphate of ammonia production and subsequently to the

production of ammonium phosphate. Imported Chilean nitrate of soda became relatively less abundant, and a higher proportion of nitrogen-containing fertilizers were, therefore, of the ammonia type. Fixation of nitrogen as nitric acid was first developed as a commercial process in Norway, and led to the production of nitrate fertilizers, principally calcium nitrate, but later some sodium nitrate was also manufactured. Calcium nitrate is not too easily handled owing to its hygroscopic character, and does not find any extensive use in this country, although it has been an important source of nitrogen on the Continent.

Calcium cyanamide is another synthetic nitrogen product which had a limited use in this country, and before the outbreak of war in 1939 its physical condition had been much improved by adding a small proportion of oil to the otherwise very dusty powder.

The inorganic nitrogen fertilizers fall into one or other of three groups:

(*a*) Processed material from naturally occurring deposits, e.g. Chilean nitrate of soda.

(*b*) By-products from industrial processes, e.g. gas-works sulphate of ammonia.

(*c*) Chemically-synthesised compounds, e.g. materials produced from the fixation of atmospheric nitrogen as ammonia, nitric acid or calcium cyanamide.

The production of (*a*) and (*b*) type materials must be limited by the extent of the natural deposits or the capacity of the industrial processes, and it may be influenced by competition from the nitrogen fixation products. The possibility of development in types of nitrogen fertilizers and in their more economic production will mainly depend, therefore, on developments in synthetic nitrogen fixation processes. As between the three existing types of process, i.e. the cyanamide, ammonia and nitric acid syntheses, the deciding factors are mainly economic, e.g. the relative costs of electric power, coal or coke and the relative capital expenditure on the different types of chemical engineering plants.

Liquid or "Anhydrous" Ammonia.—Several interesting developments have been reported from the U.S.A., which may influence the future trends in the use of synthetic nitrogen. The first is the use of anhydrous ammonia as a direct fertilizer. Ammonia (NH_3) is a gas at ordinary temperatures and pressures, but it can readily be condensed under moderate pressure to a liquid. Since the liquid ammonia does not contain any water, in contrast to solutions of ammonia in water, it has become known by the term "anhydrous" ammonia. By using pressure tanks for transporting the liquid ammonia and special types of distributing machines, it has been possible to apply the gas which is formed when the liquid is injected into the soil, in such a way that there is no appreciable loss of ammonia. The gas is liberated a few inches below the surface and provided it comes into immediate contact with soil it is absorbed and dissolved in the soil moisture or held by the soil colloids. This technique has developed rapidly, particularly

in the Southern States of the U.S.A., and in 1947 it was estimated that 200,000 acres were treated in this way, mainly land carrying row-crops, such as maize or cotton. Since the primary product of nitrogen fixation —(NH_3)—does not need to be converted into an ammonium salt, the cost of production is less per unit of N than for sulphate of ammonia. In 1947 the unit price of nitrogen in the U.S.A. in the form of anhydrous ammonia was about half that in the form of sulphate of ammonia. The liquefied ammonia has the advantage of very high concentration, 100 lb. being equivalent to just over 82 lb. of nitrogen. Against the advantages of lower cost per unit and high concentration must be placed the cost of the special equipment for transporting, storing and applying the liquid form and the probable limitation in use to crops planted in rows between which the liquid can be injected into the soil. In Great Britain there would seem to be a possibility of its use in this way as a top dressing for brassica crops and, perhaps, sugar beet, and other uses for this form of nitrogen fertilizer might be developed with experience in its use.

Nitric Acid.—The second interesting development is in a report published in 1946 of a new process for the direct synthesis of nitric acid which does not require the electric arc technique. Research workers at the University of Wisconsin are reported to have devised a process whereby temperatures of 4,200° F. can be obtained from a heat exchange two-way gas-fired furnace. At this temperature the oxidation of atmospheric nitrogen to nitric oxide takes place to an appreciable extent and nitric acid can be produced. The necessary equipment is said to be relatively simple, and capable of being built as a small-scale commercial unit. Should this process prove economically practicable it may lead to the production of nitric acid, and thus of nitrate fertilizers, in areas where, owing to lack of cheap electric power, it has not hitherto been possible. Whether it would compete with the other alternative to the electric arc process, i.e. the catalytic oxidation of synthetic ammonia, would, of course, depend on the economics of the two processes.

Urea Compounds.—A further development, which has very attractive possibilities, is the manufacture of insoluble materials from urea and formaldehyde. Large-molecule condensation products of urea and formaldehyde are insoluble in water, and the availability of the nitrogen depends on the decomposition of the compound in the soil. It seems probable that this decomposition would take place through biological activity and the rate of release of available nitrogen might run parallel with the rate of biological activity in the soil, which itself would be related to the rate of plant growth. In this way the material would supply nitrogen to the plant more or less according to its needs throughout the growing period. In other words, this synthetic plastic type of material would be comparable to the nitrogenous "organic" materials such as hoof and horn meal, which provide a source of slowly available nitrogen. The commercial production of a material of this kind was commenced in the U.S.A. in 1948, and marketed

under the name of "Uraform." Until large-scale production is possible it is probable that the unit cost of nitrogen would be much higher in this form of compound than in the other synthetic products such as ammonia or nitric acid. A similar type of plastic compound can also be prepared from casein, but in this case the raw material is of animal origin and, therefore, expensive.

Ammonium Nitrate.—The production in America of ammonium nitrate in a form which is stable and can be handled conveniently and stored for reasonable periods under farm conditions is an example of a development of a material whose fertilizer value was well known, but which possessed serious practical disadvantages for its agricultural use. W. H. Ross, *et al.*, (*U.S. Dept. Agric. Tech. Bulletin 912*, 1946) describe some of the processes which have been adopted to improve the physical condition of ammonium nitrate. The solid can be obtained either in single crystal form or as grains or pellets by spraying processes. The grains and pellets are both more porous than the single crystal form and have a greater tendency to absorb water and become deliquescent. A granular type of fertilizer possessing good storage properties can be obtained by the addition of conditioning agents such as Celite, Kieselguhr, Kaolin, or clay along with water repellents. When packed in waterproofed paper bags the conditioned ammonium nitrate has maintained satisfactory mechanical condition for at least a year, even in the most humid sections of the country.

It seems probable that similar treatment with conditioning agents and water-repellents could be applied to improve the handling and storage properties of other highly deliquescent fertilizers, such as calcium nitrate, and compounds containing these substances.

Ammonia Solutions.—Another development in the use of ammonium nitrate has been the production of solutions of ammonia gas in concentrated solutions of ammonium nitrate, and the use of these solutions in the manufacture of compound fertilizers. Solutions containing a high percentage of ammonia and urea have also been used in this way. Typical analyses of ammonia solutions commercially available in the U.S.A. are as follows:

(1) *Ammonia—Ammonium Nitrate solutions.*

				Nitrogen		
	Ammonium Nitrate	Ammonia	Water	as Nitrate	as Ammonia	Total
(*a*)	65%	21·7%	13·3%	11·4%	29·2%	40·6%
(*b*)	66·8%	16·6%	16·6%	11·7%	25·4%	37·1%

(2) *Ammonia—Urea solutions.*

			Nitrogen		
Urea	Ammonia	Water	as Urea	as Ammonia	Total
43·3%	30·7%	26·0%	20·2%	25·3%	45·5%

The unit cost of nitrogen in these solutions is appreciably less than the unit cost in the form of sulphate of ammonia, the difference in 1947 being about 14 per cent. A price differential of this amount is of economic importance to the fertilizer manufacturer and, also, to the farmer.

One of the most important uses of these ammonia solutions or liquors

in the U.S.A. has been the production of ammoniated superphosphate containing between 2·5 and 4·5 per cent. of nitrogen. Ordinary superphosphate always has an acid reaction due to the presence of a small amount of free phosphoric acid, and this may lead to the formation of hydrochloric or nitric acids when the superphosphate is mixed with chlorides or nitrates in the making of compounds. The addition of ammonia neutralizes the acidity and may also produce ammonium phosphate by interaction with the acid calcium phosphate in the superphosphate. There are some resulting changes in the composition of the calcium phosphate, and in the ammoniated superphosphate the phosphate exists partly as water-soluble $Ca(H_2PO_4)_2$ and partly as water-insoluble $Ca_2(HPO_4)_2$ (dicalcium phosphate) and $Ca_3(PO_4)_2$ (tricalcium phosphate). Although not soluble in water these phosphates, particularly dicalcium phosphate, are soluble in neutral solutions of ammonium citrate and, therefore, rank as available phosphate (A.P.A.) in the U.S.A.

Since ammoniation of superphosphate results in a decrease in the amount of water-soluble phosphate, manufacturers in this country would be handicapped by the Fertilizers and Feeding Stuffs Act requirement of a statutory declaration of water-soluble P_2O_5 in the ammoniated superphosphates. The advantage of ammoniation, beyond the addition of nitrogen, lies in the better physical condition of the ammoniated superphosphate and the freedom to mix it with other chemical fertilizers without the fear of undesirable interactions.

Phosphatic Fertilizers.—Superphosphate has for more than 100 years been the main phosphate product of the fertilizer industry, which was, in fact, built up on this process. Basic slag has been the other important source of phosphate, and these two materials together provided practically all the phosphate on the farm until the recent large-scale production of ammonium phosphate. Bone products have always been in demand as fertilizer, but the very limited supply could not keep pace with the ever-increasing demand and they do not now provide more than a small percentage of the total supply of phosphate.

Superphosphate manufacture in this country requires the importation of phosphate rock from those areas where naturally-occurring deposits are found. The "rock" is a very variable material, but in most cases the phosphate is present in the apatitic form, either fluorapatite ($Ca_{10}(PO_4)_6F_2$) or carbonate apatite ($Ca_{10}(PO_4)_6CO_3$) and in most deposits the former is the principal or only form. The comparative ineffectiveness of rock phosphate as a fertilizer, even when very finely ground, is largely due to the very low solubility of fluorapatite. The conversion of the natural material into a more effective fertilizer requires the conversion of the fluorapatite into a form which is more soluble in the soil moisture or can become soluble through biological activity in the soil. The first process which produced this result was the treatment of the ground rock phosphate with sulphuric acid in the manufacture of superphosphate.

The treatment decomposes the fluorapatite and some, but not all, of the fluorine is liberated during the process and carried off in the gaseous products. The phosphate is converted, almost completely, into monocalcium phosphate ($Ca(H_2PO_4)_2$) which is soluble in water and, therefore, readily available to the plant in the soil.

The success of superphosphate as a fertilizer on widely different types of soil, and the comparative simplicity of the manufacturing process, requiring only one other raw material, sulphuric acid, which could be produced cheaply or was available as a by-product from other industrial processes, did not provide much incentive to look for alternative methods for converting rock phosphate into an active fertilizer. Increasing knowledge of the behaviour of phosphorus compounds in the soil and of the fertilizer value of different phosphates indicated, however, that water-solubility was not necessarily the best or only criterion of fertilizer value, and attention was directed to alternatives to the superphosphate process. The fact that crops utilize only a small part, frequently less than 20 per cent., of the phosphate added to the soil in fertilizers also stimulated the search for new compounds which might prove more efficient in this respect.

Silico Phosphate.—Research work in Britain on these lines has been very limited, and the production of a comparatively small amount of "silico phosphate" during the war years—1939-45—was stimulated by the desire to find a method of treating rock phosphate which would not require the importation of pyrites from which to make sulphuric acid. (E. M. Crowther and F. M. Lea, *Journal Min. Agric.*, June, 1946.)

This material was produced by heating to a high temperature, just short of fusion point, a mixture of rock phosphate, soda ash and silica sand in the presence of steam. This heat treatment process decomposed the apatite phosphate with the elimination of most of the fluorine and gave a product which contained a mixture of calcium silico-phosphate and calcium sodium phosphate containing about 33 per cent. total P_2O_5. On the Continent a similar product has been produced in Belgium and Germany in limited amount and marketed under the name "Rhenania" phosphate, containing between 25 and 29 per cent. P_2O_5. A material of similar type—"Röchling" phosphate—was also produced in Germany just prior to the outbreak of war in 1939, and resulted from the kiln fusion of phosphate rock with soda slag, a waste material from the desulphurization of iron with sodium carbonate in one particular process for the manufacture of steel. Fusion of rock phosphate with silicate minerals such as olivine, a magnesium silicate, has also been reported in the U.S.A.

These calcined, or fused phosphates are not soluble in water, but a high proportion of the phosphate is soluble in neutral solutions of ammonium citrate and available to plants. They generally contain an excess of alkaline material, either lime or soda, and therefore do not lend themselves to mixing with sulphate of ammonia in the manufacture of compound fertilizers. They are comparable in efficiency to high grade, high soluble

basic slag, and can be considered as alternatives to this quality of slag and suitable for the same crops and soil conditions.

Nitric Superphosphates.—In Holland considerable research work has been carried out on the treatment of rock phosphate with nitric acid and a patented process has been developed which gives a mixture of ammonium nitrate and dicalcium phosphate. By modifying the process, calcium nitrate can also be formed. A similar technique was developed in South Wales and taken to the pilot plant stage in 1947. In this case a granular fertilizer was produced containing about 20 per cent. nitrogen and 20 per cent. phosphoric acid (P_2O_5).

T.V.A. Products.—By far the most numerous and most interesting developments in phosphate technology have been those initiated by the U.S. Department of Agriculture and the Tennessee Valley Authority (T.V.A.) since its constitution in 1933. The T.V.A. undertook large scale research work on fertilizer manufacture as part of its multi-sided activities connected with water control in the Tennessee Valley. The annual reports of the Authority provide a fascinating and detailed account of the work of which only a brief account can be given here.

Deposits of rock phosphate existed in Tennessee and T.V.A. produced vast amounts of hydro-electric power at a very low cost. It was natural, therefore, that attention should be concentrated on processes which depended on power supply and which could be applied to raw materials of even low grade. Research is being continued on a vast scale, but the more important products which had been developed in the first fourteen years' work included the following:

(1) Elemental phosphorus from rock phosphate by an electric furnace technique.

(2) Phosphorus pentoxide (P_2O_5) and phosphoric acid (H_3PO_4) by burning phosphorus and absorbing the P_2O_5 in water.

(3) Triple superphosphate containing about 47 per cent. available P_2O_5 by treating rock phosphate with concentrated solutions of phosphoric acid.

(4) Calcium metaphosphate ($Ca(PO_3)_2$), by treating lump rock phosphate with vapourised P_2O_5. This compound contains phosphorus equivalent to about 60 per cent. P_2O_5.

(5) Fused tricalcium phosphate produced by a relatively simple and inexpensive heat treatment process and containing 26 to 30 per cent. P_2O_5.

Triple superphosphate, calcium metaphosphate and fused tricalcium phosphate are all of great fertilizer interest and have been produced in commercial quantities. In 1947 the T.V.A. production of triple superphosphate was 7,800 tons, and of fused tricalcium phosphate 24,000 tons. Triple superphosphate can be produced by other methods and it is manufactured in America and in Europe by the so-called "wet-process," involving the preparation of solutions of phosphoric acid by treating rock phosphate with sulphuric acid. Whether this process or the electric furnace process

is the more economic depends on the cost and availability of supplies of sulphur or pyrites and on the cost of electric power.

In addition to the above products, T.V.A. have carried out experimental work, in some cases to the pilot plant stage, on the production of several other fertilizer materials. These include (1) diammonium phosphate $(NH_4)_2 HPO_4$, a highly concentrated material containing about 54 per cent. P_2O_5 and 21 per cent. nitrogen, (2) dicalcium phosphate produced with ammonium nitrate as a separate product by treating rock phosphate with nitric acid, (3) potassium metaphosphate, a compound containing the equivalent of 55 per cent. P_2O_5 and 35 per cent. K_2O and (4) a compound metaphosphate containing both potassium and magnesium by a process involving the treatment of the mineral "polyhalite" with phosphorus pentoxide or phosphoric acid.

In the preparation of all these materials the emphasis has been on high concentrations of plant food elements with the object of economy in transport costs. This factor may become of increasing importance in the supply of fertilizers to many tropical areas, e.g. in Africa, which do not possess either the manufacturing facilities or the supplies of the essential raw materials necessary for local manufacture.

Potassic Fertilizers.—Developments in this case, apart from the production of potassium metaphosphate, have been very few. The source of practically all the potash fertilizers lies in the deposits of potassium salts occurring in various parts of the world which have been formed by the drying out of ancient inland seas or salt lakes. The potassium is present in different mineral forms in different areas, but the two most important minerals are carnallite, a double chloride of potassium and magnesium, and sylvinite, a double chloride of potassium and sodium. The various grades of potassic fertilizers, i.e. kainit, potash salts, muriate of potash (potassium chloride) and sulphate of potash (potassium sulphate) are produced by grinding the salt as mined or by recrystallisation or other processes to separate and purify a potassium compound.

Potassium sulphate cannot be directly separated from some of the salt deposits and it is necessary to treat the chloride with sulphuric acid in a separate process. This adds to the cost of production and makes the unit cost of K_2O about 4*s.* 7*d.* as chloride and 7*s.* 10*d.* as sulphate (1948 prices). The use of sulphate of potash is justified, therefore, only where it can be shown to be more efficient per unit of K_2O or when the presence of chloride in the compound is undesirable, e.g. for intensively manured glasshouse crops, particularly tomatoes, and for red currants and some other soft fruits.

LIME AND LIMING

No account of "manuring" would be complete without some reference to the complementary practice of liming. In some parts of the country, particularly in the wetter parts, liming is essential to the proper functioning of either farmyard manure or fertilizers, and no amount of expenditure on

either of the latter can be profitable if the correction of serious soil sourness is neglected. Our forefathers appreciated the value of lime long before they knew anything about fertilizers, and the practice in olden times was commonly to dress fields with what would now be considered quite unnecessarily heavy quantities of lime. This was particularly the case in those areas where chalk was readily obtainable or where a lime-containing marl underlay the soil. Old chalk or marl pits are a well-known topographical feature of certain parts of the country.

Unfortunately, the practice of either occasional heavy liming or systematic rotational liming had been neglected, particularly on the poorer soil farms which most needed it, for quite a number of years prior to the introduction of the lime and slag subsidy scheme in 1937. During the years of agricultural depression up to 1937 the consumption of all forms of liming materials in the United Kingdom probably never exceeded 600,000 tons per annum, representing approximately 400,000 tons of pure lime. This corresponded to only 28 lb. for each acre of agricultural land (excluding rough grazings), an amount which was insufficient even to replace the estimative average annual loss of lime in drainage waters. This meant that, taken as a whole, farmers were not able to prevent the slow but steady deterioration in lime status and the corresponding increase in acidity which was one factor contributing to the loss of soil fertility on many farms.

Types of Liming Materials.—Before dealing in more detail with the subject of liming, it may be advisable to say something about the different forms of lime, since a variety of materials are frequently included in the general term "lime." Chemically, all liming materials are compounds containing calcium, and the most abundant naturally-occurring compound of calcium is carbonate of lime, chemically described as calcium carbonate. The calcium compounds, such as silicates, in the primary rock minerals, are the original source of this carbonate of lime, which has been precipitated out of solution in sea water where the products of the weathering of the silicate rocks eventually accumulated. This maritime deposit forms what we call chalk, and the older and more consolidated deposits are found as limestones of various geological ages.

Chalk and marl quarried from a soft deposit can be utilized as a liming material without any further treatment, but some chalks and all limestones are too hard to be used directly without grinding down to a fine powder. When either of these forms of carbonate of lime is heated in a kiln to a high temperature, the chemical compound is decomposed and the gas carbon dioxide is liberated, leaving behind the oxide of lime or calcium oxide. This product from the heating or "burning" of chalk or limestone is known as burnt lime, and also as shell lime, lump lime and cob lime. The term "quick lime" is also given to it since it possesses the property of combining with water, or slaking, and giving out a considerable quantity of heat in the process. The slaked lime is known chemically as calcium hydroxide and is commonly described as hydrated lime.

These three chemical compounds of calcium, the carbonate, the oxide and the hydroxide are, therefore, all lime compounds, if we use the term "lime" in place of the chemical name of the element—calcium. From the point of view of their efficiency as liming agents it is the amount of calcium which they each contain which is the determining factor. It is customary, however, to compare them in terms of their equivalent amounts of pure calcium oxide, i.e. pure burnt lime, although neither the carbonate nor hydrate of lime actually contain the oxide as such. The relative calcium oxide values for the three forms, assuming each to be chemically pure, are:

Burnt Lime	100
Hydrated Lime	74
Carbonate of Lime	56

The calcium oxide (CaO) content is taken as the basis for the valuation of all forms of liming materials. The above figures for hydrated lime and carbonate of lime are the highest which can be obtained for these two forms, even in the very purest materials, and commercial products will have CaO values somewhat less than these.

The other method of comparison which is sometimes more useful as a farm standard is given by the amounts of the different materials which are equivalent to a given weight, say, 1 ton, of burnt lime. These are as follows in terms of the pure materials, and also of the average grades of commercial products.

Pure burnt lime	20 cwt.
Best hand-picked burnt lime	21 cwt.
Average lump lime	24 cwt.
Pure hydrated lime	26·4 cwt.
Commercial hydrated lime	30 cwt.
Pure carbonate of lime	35·8 cwt.
Average ground limestone	40 cwt.
Ground white chalk	40 cwt.
Ground grey chalk	45 cwt.
Industrial waste limes	between 50-70 cwt.

The general rule for this calculation is to divide 2,000 (20 × 100) by the percentage of CaO in the liming material to get the quantity equivalent to 20 cwt. of pure burnt lime. Under the terms of the Fertilizer and Feeding Stuffs Act (1926), burnt lime, hydrated lime and ground limestone must have the percentage of equivalent pure lime (CaO) declared by the seller and from this the quantity of any particular grade or type of material which is equivalent to 1 ton of pure lime can be calculated by the above rule.

In addition to these ordinary forms of lime, brief mention may be made of some of the low-grade materials such as industrial waste lime, which can be used as liming materials.

Limestone "dust" is produced as a by-product from the crushing of limestones for road metal. It is frequently rather gritty and a good estimate of its value as a liming material is to pass it through the fingers to feel the range of fineness. This may vary from 20 to 35 per cent. passing through the 100-mesh sieve, and the upward range is frequently indistinguishable from

coarse ground limestone and usually as efficaceous. Occasionally it may be contaminated with clay matrix from the parent rock, in which case the equivalent calcium oxide content will be rather lower than that of clean stone. Production surplus to current demand is customarily stored in the open at the works, and, despatched from such a source, it may be difficult to spread. Otherwise it is quite satisfactory if applied at rather greater rates per acre than would be calculated from its CaO value. A slight moisture content is sometimes advantageous to damp down the dust in spreading. A well-graded coarse material is often preferred because of its "free-running" properties when applied by a fertilizer drill.

A very useful by-product lime is available from beet sugar factories, and its only disadvantage is its wetness. It may contain up to 50 per cent. of water, and this adds to the transport costs if it has to be carted any distance from the factory. This, and one or two other waste limes, contains a small amount of nitrogenous material, and this may be equivalent to a light dressing of nitrogen fertilizer. They are used at double the rate per acre appropriate for ground limestone.

Waste limes are available from a number of other industrial processes, e.g. paper-making, tanning, tar-distilling, and water-softening. These are invariably moist materials containing about 40 to 50 per cent. of water. They may contain small amounts of alkali (sodium carbonate) but seldom in any dangerous quantity. They may provide a cheap source of lime when they can be obtained locally, and if they have been "approved" by the Ministry of Agriculture for the purpose of the subsidy scheme, their quality can be assumed to be satisfactory.

A material of a different kind which has been found to possess a useful liming value is blast furnace slag, of which large dumps exist in different parts of the country. The lime, in this case, is not present as oxide or carbonate but as silicate. This decomposes, however, in the soil and the ground slag has about the same lime value as ground limestone. However, this, and other forms of calcium silicate, have not been recognised officially as liming materials qualifying for subsidy under the Land Fertility Scheme.

Consumption of Lime.—Prior to the outbreak of war in 1939 the greater part of the lime used in this country was in the form of burnt lime, and there was a definite prejudice among farmers against ground limestone. Approximately two-thirds of the annual consumption of agricultural liming materials was as burnt lime, and, since agricultural lime represented only about 20 per cent. of the total lime production in the country, there was no difficulty in meeting the demand for burnt lime. The tremendous industrial and service demands for burnt lime and limestone during the war years, together with the increasing agricultural demand, soon led to a difficult supply position.

The increase in agricultural consumption is illustrated in the following table, which gives the total tonnages of all grades of lime used for agriculture during the years 1937-46.

Year		*Total lime tonnage*
1937	approximately	600,000
1938	,,	1,700,000
1939	,,	1,300,000
1940	,,	1,500,000
1941	,,	1,800,000
1942	,,	4,100,000
1943	,,	4,600,000
1944	,,	3,300,000
1945	,,	3,400,000
1946	,,	2,700,000

The effect of the 50 per cent. subsidy introduced in 1937 on the cost of lime delivered on the farm is shown by the two- to three-fold increase in consumption during the years 1938-42. The tremendous jump in consumption during 1942 and 1943 was probably due to a number of additional factors, the chief of which may have been the farmer's better financial position after two or three war-time harvests. Also, during the summer months of 1942 and 1943 the rate of subsidy was increased from 50 per cent. to 75 per cent. and 60 per cent. respectively, in order to stimulate an out-of-season demand which would help to level out the demand on production. Another factor was the large acreage of grassland which had been ploughed out by that time, and which farmers had come to realize needed liming if it was to crop satisfactorily. Yet a further factor was the change in taxation procedure, introduced in the 1942 budget, by which approximately 100,000 farmers were called on to make returns under Schedule "D" for Income Tax assessment. There was an obvious and entirely justified desire to return to the land some of the benefit arising from the better war-time prices, and lime was one of the few unrationed commodities, still in fairly good supply.

It seems fairly clear that the farmer's demand for lime was closely influenced by farming profitability and that the low pre-war demand was more a reflection of his poor financial position than of his ignorance of the benefits to be derived from really adequate liming.

The sudden increase in the use of lime in 1942, occurring as it did at a time of shortage of labour, fuel and power, meant that the increased demand could not be met by providing increased supplies of burnt lime, and alternative materials, mainly ground limestone, had to be used. Through the Agricultural Lime Department (United Kingdom) every effort was made to develop existing sources of supply and to find new ones, either by making use of existing dumps of suitable industrial waste limes, or by initiating the installation of new grinding plants at limestone quarries. In this way the production of ground limestone was raised to over 1,000,000 tons per annum before the end of the war, an increase of about 500 per cent. as compared to pre-war output.

About this time, also, experimental evidence was accumulating which showed that the old idea could not be maintained that limestone must be ground to a very fine powder before it could be effective. The standard test

for fineness of grinding is given by the proportion of a sample which passes the 100-mesh sieve and it used to be considered necessary to get a fineness of grinding such that between 70 to 80 per cent. passed through this sieve. Grinding to give 50 to 60 per cent. through the prescribed sieve became the more usual practice, and results in the field have amply confirmed the experimental evidence. In fact, it is probable that even coarser grinding to give about 30 to 40 per cent. through the 100-mesh sieve, provided the remainder is not too "gritty," would be equally effective and give a material which would be very suitable for mechanical distribution.

Magnesian Lime.—Another development in liming during the war years was the gradual breaking down of the prejudice against magnesian or dolomitic limestones and burnt limes. Magnesian limestone contains both calcium carbonate and magnesium carbonate, and it was at one time considered that the latter was of little value in correcting soil acidity. Also, burnt lime from a dolomitic stone does not slake so readily as ordinary lime and may be injurious to grass or to crops if used at rates much in excess of 2 tons per acre. Both ground magnesian limestone and burnt lime have been used satisfactorily for many years in Yorkshire, but in other parts of the country they were given a bad reputation and were avoided. Although the slow slaking of burnt magnesian lime may sometimes be a disadvantage, experience has shown that the magnesian carbonate plays a part in neutralising an acid soil and that the ground magnesian limestone can be used as successfully as any other limestone and may, in some cases, be better. Ground dolomitic limestone has been found to be a very suitable material for use on acid soils deficient in magnesium and it has been used for this reason in some of the fruit-growing areas where this deficiency has been recognised as prevalent.

The Application of Lime.—The method and time of applying lime is seldom very critical under British farming conditions. It is generally applied before one or other of the acid-sensitive crops, such as sugar beet, roots or clover. Burnt lime is frequently applied before autumn-sown wheat in the south and before a spring cereal in the north, particularly when the cereals are to be undersown with seeds. There are instances of unusual liming practices in certain parts of the country, e.g. in Cheshire it is sometimes applied to the potato drill before the final earthing up. On land subject to "finger and toe" a heavy dressing of lime is commonly given before a brassica crop to keep the fungus in check.

Lump lime is usually carted on to the field and laid out in small heaps of a few hundredweight to slake by absorbing moisture from the air. It is necessary to spread it from the heaps as soon as properly slaked and before it has become too wet. This spreading is almost always by hand and in practice it is difficult to get anything like an even spread with less than 2 tons per acre. Where light dressings are given, ground burnt lime or ground limestone can be applied with a fertilizer drill or by special lime distributors designed to sow rates up to 2 tons, or more, per acre. When lime is spread

on arable land it is advisable to follow with the harrows to work the lime into the surface soil, although it is not considered good practice to work lime deeply into the soil.

There are, however, certain circumstances under which it has been found very useful to plough lime down to some depth. When areas of heath and scrub land on light sandy soils were cleared for cropping during the war period it sometimes happened that a surface liming was insufficient to correct the high acidity to a sufficient depth for a deep-rooted crop such as sugar beet. Under these circumstances half the lime should be applied before ploughing and the remainder on top of the furrow to be worked into the surface soil.

Lime can be applied to grassland at more or less any time of the year, but burnt lime is usually spread during the winter or early spring months. Ground limestone can be used even during the growing season and stock can graze pastures immediately after they have been dressed, although it may be better to wait for the first shower of rain to wash the dust off the herbage.

The Future Lime Position.—As a result of the soil acidity surveys conducted by advisory chemists, it is known that there are many millions of acres of agricultural land in the country which require liming, and much of this sour land needs a dressing equivalent to 2 tons of CaO per acre. The cost of this treatment is not inconsiderable, even allowing for the 50 per cent. subsidy. During the war years the cost of lime delivered on the farm increased by about 50 to 60 per cent. and the cost of 1 ton pure lime (CaO) supplied in the different forms of liming materials in 1945 was approximately as follows:

Lump burnt lime	60*s*.	(excluding subsidy payment)
Ground burnt lime	80*s*.	—do—
Hydrated lime	100*s*.	—do—
Ground chalk and limestone	60-70*s*.	—do—
Low grades (wastes, etc.)	40-45*s*.	—do—

The cheapest form of lime on the farm was frequently the low-grade material (including industrial waste limes) but against this lower cost must be set the higher cost of spreading the substantially greater weight required per acre. One of the reasons for the comparatively high cost of ground chalk and limestone lies in the different method of handling compared with burnt lime. The latter is usually delivered loose in bulk, whereas the ground chalk and limestone is frequently delivered in non-returnable bags. The cost of these would probably amount to about 10*s*. per ton, and if allowance is made for this the price advantage probably lies with ground chalk and limestone.

The war-time increase in cost of lime was not, however, as steep as the increase in the price of agricultural commodities, and with the benefit of the 50 per cent. subsidy, the real cost to the farmer was much less than before 1937. Whereas the average delivered cost of burnt lime was about 30*s*.

per ton in 1939, the cost in 1945, after allowing for the subsidy, was in the region of 23s. Over the same period the official general index price of agricultural produce rose from 90·5 to 170. This meant that in 1935 the price of one ton of lime to the farmer had fallen to the equivalent of 12s. 3d. worth of produce at 1939 price levels. In other words, where 10 sacks of wheat were required to pay for a certain amount of lime in 1939 (excluding subsidy) only a little over 4 sacks were required in 1945 to pay for the same amount.

The two facts, the farmer's better financial position and the 50 per cent. subsidy, undoubtedly make it possible for the average farmer to undertake more liming than in the past, but, even so, it still costs about 60s., on the average, to dress those fields which are most in need of lime at the rate of 2 tons of CaO per acre. In districts some distance from the nearest supply of lime it may cost considerably more, due to higher than average transport costs. Unfortunately those districts frequently are just those where liming has long been neglected and where the farmer is, perhaps, least able to afford the expenditure.

Although the post-war consumption of lime of about 2,000,000 tons of CaO on the farms of the United Kingdom is probably well below the quantity necessary to build up high soil fertility and a healthy livestock population, the maintenance of the demand, at even this level, will probably depend very largely on the trend in price levels for produce and lime, and the continuation of the assistance given by the subsidy scheme. The relationship between farm profits and lime consumption was shown during the peak period of war-time demand in 1943-44 by the fact that those areas where the use of lime was greatest were, in the main, the arable districts in the south and south-east which benefited most from the higher cereal prices, although their real need for lime was probably less than in other parts of the country.

The other important factor likely to influence the farmer's use of lime is labour, both in amount and cost. The mechanization of lime spreading seems to offer the only hope of reducing the demand on farm labour, and the extension of the contract system developed during and since the war may well prove to be the most practicable solution on many farms. A substantial tonnage of lime, mainly ground chalk or limestone, but also including ground burnt lime, is now spread each year by contractors using their own specially-designed distributor lorries at an inclusive cost to the farmer. Ground chalk and limestone lends itself particularly well to this practice, since the material is in a suitable mechanical condition for spreading, and can be applied during most seasons of the year, particularly on grassland. It is neither caustic nor corrosive and the bulk transport and handling eliminates the cost of paper bags which may represent a considerable fraction (up to a quarter) of the final cost to the farmer.

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CHAPTER 3

TILLAGE CROPS

By D. H. Robinson

ROTATIONS

It has long been recognised that to crop a field year after year with the same crop is an undesirable practice. There is even a feeling that, in many cases, it is a mistake to allow even grass to occupy the land too many years in succession—that permanent pasture is frequently unprofitable. In all countries where agriculture has been practised over many centuries, it has been shown by experience that some more or less regular succession of crops is essential if farming is to continue. This succession of crops is desirable in order to

(1). Maintain fertility

(2). Control weeds and pests

(3). Ease labour problems.

1. To Maintain Fertility.—Any crop removed from a field impoverishes the soil to the extent of the mineral elements present in the crop. The loss may be absolute if the crop is sold off the farm, or only partial if some of the produce is fed to animals and returned to the field in the form of farmyard manure. Crops like wheat and barley, and potatoes, which go off the farm, are "exhausting" crops, and if this process of selling off (including possibly straw and hay as well) were to go on for a long time, the fertility of the soil would be diminished below the stage of profitable farming and might indeed be utterly ruined. There is, of course, a slow process of soil weathering by which mineral elements gradually become available to plants, but this is not rapid enough to compete with the removal of minerals by continuous cropping. The humus, or organic matter, of the soil is also reduced by continuous arable cropping and cultivation, and this can be renewed only to a limited extent by dunging.

To maintain and increase the humus it is necessary to grow crops with a plenteous root system as well as top growth, and plough them into the ground either grazed or ungrazed. A catch crop like mustard can be turned under as "green manure," but it has been found more generally useful to use a ley of mixed grasses and clovers; the clovers not only add humus, but also some nitrogen collected from the air by bacteria in the root nodules. Beans and peas do the same, or a crop of turnips, heavily

dunged and folded off by sheep, can be used to restore fertility. The principle is that "cash" crops must at intervals be followed by crops whose main object is to restore humus and fertility.

2. The Control of Weeds and Pests.—Cereal crops drilled in narrow rows and occupying the ground (in the case of winter wheat and beans) for ten or eleven months of the year, encourage the growth of annual and perennial weeds. Soon there comes a time when the weeds are so numerous that a profitable crop can no longer be grown. To prevent this happening, crops of a different habit of growth must be alternated, or the land must remain cropless for a year and be worked as a bare fallow to kill weeds. A properly arranged sequence of crops does much to keep the land clean; roots, such as potatoes, sugar beet and turnips, sown in wide rows and kept well hoed, will "clean" the land, though if not properly looked after they can be as "dirty" as any cereal. Smother crops such as mixtures of oats, peas and vetches, or broadcast kale, can also be used. Long leys prevent the germination of seeds of annual weeds, but may encourage perennial weeds.

There is always a tendency for crops grown year after year on the same land to become seriously attacked by fungus and insect enemies. Finger-and-toe (or club root) in turnips and cabbages, rot in red clover, and wart disease in potatoes are classic examples of fungus diseases which develop when these plants follow each other too closely on the same land. Eelworm disease in sugar beet, potatoes, peas and oats is very serious indeed in some parts of the country where too close a rotation has been practised over many years. Wide spacing in time of similar crops by means of a sensible rotation is the soundest method of controlling diseases of this kind.

3. To Ease Labour Problems.—It is obvious that if only one crop were grown on a farm, say winter wheat, there would be periods of intense activity at seeding and harvesting, with months of inactivity in between. At the active periods the strain on the labour force would be immense, while in between, the workers would not be earning their keep. A succession of crops, however, enables the fullest use to be made of available labour, and gives more time for the land to be prepared for the various crops.

EXAMPLES OF ROTATIONS

The old Norfolk four-course rotation, which in some parts of the country was most rigidly observed up to the 1914-18 war, is a good starting-point; it was:

Wheat: Roots: Barley or Oats: Seeds.

Wheat and barley are cash crops; roots are the cleaning crop; seeds planted in the barley provide fodder (hay) and humus, and if dunged ensure plenty of nitrogen and phosphates for the wheat. This rotation has several disadvantages; it is expensive in labour and there are only two

cash crops in four seasons; it was often lengthened on heavy land by putting in another straw crop, thus:

Wheat: Winter Oats: Roots: Barley: Seeds.

On lighter land the extra straw crop usually came after the root break:

Wheat: Roots: Barley or Oats: Barley: Seeds.

Another method of reducing costs of working and increasing the humus content is to let the seeds ley remain down for two or three years, transforming the sequence into a five- or six-course rotation. This is really the basis of the so-called "ley farming" system, which has been common practice in the moister parts of England and South Scotland for a very long time. If the three-year ley is a good one and is ploughed up while still vigorous, the plant residues plus judicious, fertiliser dressings should be sufficient to grow satisfactory corn and root crops for five or more seasons. In East Anglia, however, there is often a difficulty in maintaining a profitable three-year ley.

In potato-growing districts the sequence of crops may be different, since a good clover ley makes excellent preparation for potatoes. The rotation is a six-course:

Wheat: Oats: Roots: Barley: Seeds: Potatoes.

Here there are at least three cash crops and two cleaning crops in six years. The fullest use can be made of the one-year seeds, and there is ample time in every case to prepare for the next crop.

Nowadays rotations are not followed so rigidly as formerly, though the general principles already mentioned are, in the main, observed. The spread of market-garden crops on to farm land, the introduction of herbage seed crops, developments in the technique of ley formation, shortage of livestock, fluctuations in prices, all these encourage a farmer—at least on easy working land—to vary his cropping according to the degree of profitability. Provided the general principles of good husbandry are observed, flexibility in cropping sequence is a good thing.

WHEAT

In general it may be said that wheat does best on medium to strong soils in areas having only a moderate winter and early autumn rainfall. The eastern and southern parts of England, with their drier climate, grow most of the wheat. Before the advent of the combine harvester and grain drier it was essential to have good weather at harvest, with the consequence that over much of the northern and western districts wheat was very little grown. The combine harvester has greatly simplified wheat growing and has made it possible to grow the crop in districts once thought quite unsuitable. On very fertile soils, such as in the fens and on good, old turf recently ploughed, wheat stands up better than any other cereal, especially the newer, strong-strawed varieties. Furthermore, the introduction of improved

Varieties of Wheat

Variety	Straw Length and Standing Quality	Colour of Chaff	Colour of Grain	Remarks
1. Winter Wheats				
(a) First quality bread-making varieties				
Holdfast	Medium: excellent	White	White	For medium-heavy, highly fertile soils. Liable to sprout in the ear.
Redman	Medium: good	Red	Red	For very fertile soils.
Warden	Medium: fairly good	White	White	For good soils not of the very richest type.
Yeoman	Medium: very good	White	Red	For very fertile soils: rust resistant.
(b) Medium quality, biscuit-making varieties				
Wilhelmina ..	Medium: good	White	White	These four varieties are very similar. They are all suited to soils of average fertility with a rainfall exceeding 25 inches. In the western half of the country they are very reliable croppers. Juliana has slightly shorter, stronger straw than the others.
Wilma	Medium: good	White	White	
Victor	Medium: good	White	White	
Juliana	Medium: very good	White	White	
Little Joss ..	Long: moderate	Red	Red	For light soils of low fertility: lodges in rich land; resistant to rust.
Steadfast ..	Medium: fairly good	Red	Red	Can be used on rather better land than Little Joss.
Squarehead's Master	Medium: fairly good	Red	Red	Very reliable cropper for soils of medium texture and fertility; selection 13/4 is a higher yielding type.
(c) Other varieties				
Jubilégem ..	Short: excellent	White	Red	Heavy yielder, early ripener, for soils of highest fertility.
Bersée	Medium: very good	White	Red	Straw slightly longer, ripens slightly earlier; can be used as spring wheat.
Vilmorin 27 ..	Short: very good	White	Red	High yielder, early ripener. Susceptible to loose Smut.
Squarehead II ..	Medium: good	Red	Red	Similar to Squarehead's Master, but stands better.
Rivet	Long: moderate	Grey	Red	A bearded variety. For heavy soils of low fertility; late ripener. Rampton Rivet stands best and gives biggest yields.
2. Spring Wheats				
(a) For sowing before end of March				
Atle	Short: very good	White	Red	For fertile soils. An early ripener, good yielder. Excellent combine wheat. Grain small.
Vilmorin 29 ..	Short: very good	White	Red	Should be sown before end of March. For fertile soils.
Red Marvel ..	Medium: fairly good	White	Red	Is outyielded by the above varieties.
Meteor	Medium: good	White	Red	Ripens earlier than Red Marvel.
Extra Kolben II	Medium: fairly good	White	Red	
(b) For extra late planting				
April Bearded ..	Medium: fair	Red	Red	For moderately fertile soils: early ripener.
Diamond II ..	Medium: good	Red	Red	Stands better and outyields April Bearded.
Fylgia	Medium long: good	Red	Red	Grows and yields well on a great range of soils: can be planted very late, ripens early.

spring varieties has made possible the extended cultivation of wheat on the lighter soils where autumn planting is not looked upon with favour.

Varieties.—The enormous number of varieties of wheat (the total number of existing varieties is estimated at over 100) offered for sale in this country is an embarrassment to all concerned with wheat growing and the handling of the wheat flour. One of the most important reasons is that the buyer is unable to obtain bulk supplies of a uniform type, and this encourages him to purchase foreign wheats which are available in large lots of uniform type and condition. In an attempt to reduce the number of varieties without detriment to the grower, the National Institute of Agricultural Botany in conjunction with seed firms, millers, bakers and other interested parties, has made a list of recommended varieties, based upon extensive trials in all parts of the country. The list is provisional, and in no sense permanent; it is intended to add to or subtract from it as experience dictates. The table on page 103 summarises the recommendations of the N.I.A.B.

From a quality point of view wheats are of three classes; those suited to bread making, those suited to biscuit making and those which are used only to a slight extent for the above purposes. Since there is at present no differential payment for high quality in millable wheat, the farmer's chief concern is to choose a variety which will give him the greatest weight of easily harvested grain per acre irrespective of the quality of the product. It is possible that some of the Scandinavian varieties may suit his conditions better than any of the varieties listed on page 103, such as Steel, Scandia, Chevalier, Crown, Iron III, or Weibull's Standard. These wheats are not in the recommended list because they do not mill very easily, but on strong land they frequently yield a heavy, if late ripening, crop.

Place in Rotation.—In the old four-course shift wheat always followed the clover ley, which was usually mucked. Nowadays it is increasingly common for potatoes to follow the ley, and wheat to come next. Wheat is frequently grown after a fallow, or as the first crop on newly ploughed old turf. Wheat sometimes follows wheat, and because of the newer, better yielding spring varieties, the crop can be fitted into almost any part of the rotation.

Cultivations.—Winter wheat likes a solid bottom and a roughish tilth. When it follows a ley or another straw crop a shallow ploughing only is necessary, from 4 to 5 inches deep. The furrows are disced or spring-tine harrowed, and the land is ready for planting. The top-soil should be knobbly, not fine, so that it does not run together during the winter rains. The clods, which should be about the size of a man's fist, protect the plants to some extent, and in spring crumble down to a fine tilth which on stiff soils is frequently utilised for the sowing of grass and clover seeds. On light land, and also on strong land which is unusually dry, a furrow press may be used to consolidate the bottom of the furrow.

Manuring.—The tendency nowadays is to grow the wheat crop upon

the manurial residues of previous crops. After a dunged ley, after potatoes or after sugar beet, no fertilisers should be necessary in the seed-bed. If wheat is grown on a poor, old turf just ploughed up, a dressing of phosphates is almost certain to be necessary; from 2 to 3 cwt. per acre of superphosphate is a useful insurance against failure from phosphate starvation. Alternatively, 1 to 1½ cwt. per acre ammonium phosphate provides both the phosphoric acid necessary for root growth and the nitrogen to assist the rotting of the turf. Unless the old turf is in really excellent condition, some phosphate should be given at planting time, because it is not at all easy to provide a remedy for a winter-planted wheat crop which shows signs of phosphate deficiency in spring. Ammonium phosphate gives the quickest results in such cases, followed by superphosphate, with basic slag third. Wheat after wheat may need a small quantity of phosphates, but heavy applications are wasteful and unnecessary. Potash is seldom required for wheat except on very light soils which, in any case, are not really suited to wheat. Nitrogen gives the greatest return of the fertilising elements, and now that stronger-strawed varieties of wheat are available, nitrogen can be used more freely without laying the crop. It is now pretty generally agreed that late applications (April-May) of nitrogenous fertilisers will increase the yield of grain as much as early applications, with the added advantage of not increasing and weakening the "flag" or straw. The tendency is towards late and rather heavy top dressings, using 2 cwt. per acre in early to mid-May. If, however, the wheat appears sickly and nitrogen-starved soon after the New Year, there should be no delay in applying a top dressing of about 1 cwt. sulphate of ammonia or nitro-chalk per acre. An additional 1 cwt. can, if thought desirable, be given in May.

Planting.—On really heavy clays wheat is best planted in late September or early October. On lighter land early November planting gives excellent results. Although a lot of wheat may be drilled in December, the practice has only this to recommend it, that it lightens the spring work. Spring varieties such as Fylgia and April Bearded can be sown very much later than was at one time thought possible and yet give yields of over a ton of grain per acre. In fact, there is evidence to show that these and similar varieties should not be planted until the soil has been prepared with considerable care as it is for spring barley. In other words, they must not be hurried into the ground just to give them a long growing period.

Practically all wheat is now drilled, the usual width between the rows being 6 to 7 inches. The depth of drilling is 1½ to 2 inches, and it is customary to cover the seed with light harrows.

The quantity of seed used per acre depends upon the variety and the time of sowing. Holdfast, for example, has a much smaller grain than Bersée, so that a less weight is necessary to give the same number of plants per acre. For early sowing 1 to 1¼ cwt. (2¼ bushels) may be sufficient; for November sowings 1¾ cwt. (3 bushels) may be thought desirable as an insurance against loss of plant during the winter.

Seed wheat should always be dressed with an organo-mercury preparation as an insurance against Bunt.

After Cultivations.—On stiff land, the last operation in autumn is to draw out surface water furrows in order to get as much water off the land as possible. When the land is dry enough in spring the wheat is rolled and harrowed. It is important, on heavy land, not to be in too great a hurry to do these cultivations. The subsoil must be dry as well as the surface soil or the passage of the tractor may do much harm. Whether the roller or the harrow is used first can only be decided by reference to actual conditions; sometimes only one of the implements may be necessary. The object of the cultivations is to press the plants into the soil after the frosts of winter, to break down the clods, and so eliminate any surface crust.

If the wheat is very forward, or "winter-proud," in spring, there is a danger that lodging may occur later. If the plants are overcrowded some may be harrowed up by drastic cultivation. If the individual plants are too luxuriant they should be topped off either by grazing or mowing. Provided that they are turned in only when the soil is dry, both sheep and cattle can be safely used to graze wheat up to the end of April, with considerable benefit to themselves as well as the crop. Wheat is sometimes mowed in spring either for silage or for drying.

Harvesting.—When the binder is used, wheat is cut while the grain is still on the soft side but easily rubbed out between the fingers. The grain soon hardens in the stook, but if left too long it would shed badly during the handling. A clean crop, cut fully ripe in hot, dry weather, need stand only a day or two in the stook before carting; if the bulk of the sheaves are foul with rubbish, and the weather is wet, the stooks may have to stay out a fortnight. Once the crop is dry, carting can be carried out even if the sheaves are moist with dew or slight rain. Some wheat is threshed direct from the field, but it is much more usual to stack it and thresh the ricks during the winter and early spring.

When the combine harvester is used wheat should be cut dead ripe, ten days or more after it would be considered fit for the binder. The grain still contains 20 per cent. or more of moisture and must be artificially dried down to about 14 per cent. moisture before it can be stored with safety.

Yield.—The average yield of wheat in this country is about 17 cwt. per acre.

BARLEY

Barley is grown both for feeding purposes and for malting into beer or vinegar. The price offered for barleys considered to be suitable for malting is considerably higher than that usually obtainable for feeding barleys, and in the best barley-producing areas the crop is consequently grown and harvested with great care.

A good malting sample should be true to variety without admixture

of other varieties, and should be uniform in size and ripeness. It must be plump and well filled and the "skin" should be finely wrinkled. It should have an even yellow colour, without trace of dark brown at the extremity which suggests undue warmth in the stack, and it must smell fresh and clean. When cut across, the inside of the grain should be white and mealy, not "steely."

Soil and Climate.—Good malting barley can be grown only in those districts having suitable soil and climatic conditions. Areas of heavy rainfall; areas subject to extreme summer drought; very stiff soils—these are incapable of producing a regular succession of malting samples, though in freak seasons good grain can be obtained. Medium to light loams in districts of moderate rainfall produce the best malting barleys. Quite small differences in climate have a remarkable effect upon the quality of the grain; in Norfolk, for example, certain farms close to the coast are noted for the barley they produce, though the standard of production from immediately surrounding farms is itself quite high.

Varieties.—Two types of barley are grown in this country, six-rowed and two-rowed types. Six-rowed barleys are short and stumpy in the ear, which itself is more or less cylindrical, while two-rowed barleys have (usually) longer, flat ears.

Six-rowed barleys include the so-called four-rowed types; they are widely grown in some parts of the world, and the Californian grain, which before the 1939-45 war was imported for malting, was of the six-rowed type. Until quite recently in this country six-rowed varieties were grown only for feeding purposes, for whisky distilling, or for green fodder. They have the advantage of being winter-hardy. Both the typical six-rowed kinds, and the modified (or "four-rowed") six-rowed kinds of which Bere or Bigg is the commonest example, are used for grain production. Because of the construction of the ear, the bulked grain of six-rowed barleys can never be so uniform as in the two-rowed barleys.

A recent six-rowed hybrid called Prefect seems likely to fulfil, in part at least, the demand for a winter-hardy variety of malting quality. It is a cross between Spratt Archer and Praecox, a six-rowed type. It has a rather longer, laxer ear than most six-rowed types and the straw is strong, though longer than that of Spratt Archer. The grain is of a better shape and plumpness than other six-rowed barleys, and there are fewer thin, lateral grains. It has not the same value for malting as the best two-rowed barleys, but is worth consideration by those growers who must plant some of their barley in autumn.

Of the two-rowed barleys, two varieties are of supreme importance, namely Spratt Archer and Plumage Archer. Evidence collected independently by the National Institute of Agricultural Botany and by the Pure Seed Company indicate that about 40 per cent. of the malting barley planted is Spratt Archer; Plumage Archer is responsible for probably 30 per cent.

Spratt Archer has narrow ears, which are long and drooping, but provided with a short "neck" not liable to break. It tillers freely, the grain is of good malting quality and the straw is strong.

Plumage Archer has a shorter, broader, more upright ear, with a very short "neck." Grain is plump and of excellent malting quality. It is rather more popular on the stronger barley land.

Garton's 63 is a broad-eared barley popular in northern barley districts, where it ripens relatively early.

The malting qualities of these three varieties are very satisfactory, but a demand has arisen for barleys which will both ripen earlier and stand better. The development of the combine harvester has emphasised the need for strength of straw. Two Danish varieties, Kenia and Maja, have become popular with the farmer because of their shorter straw and their ability to ripen seven to ten days earlier than Spratt Archer. The maltster, however, is not quite so pleased with these varieties, which do not give such a satisfactory yield of malt as Spratt Archer and Plumage Archer.

Camton is a stiff-strawed variety with a very broad ear, which becomes twisted as it ripens. It is recommended as a feeding barley for the more fertile soils, and no claims are made for it as a malting barley.

Pioneer is a new two-rowed variety which is definitely winter-hardy, and can be sown in autumn. Its percentage of nitrogen is slightly higher than that of Spratt Archer. Sown in autumn it ripens early, and it is being extensively tried by those farmers who harvest by combine.

Place in Rotation.—Much barley is sown in spring following a root crop. Typically this crop was turnips, folded off by sheep, but now sugar beet is often substituted for turnips, and on many farms sheep are no longer kept, and the beet tops are ploughed in. Excellent crops of first-quality barley are grown on the lighter soils after folded sheep, but on some of the stronger land the crop is risky because the plants lodge through the excessive nitrogen left in the soil. Consequently barley is often taken as a second straw crop after roots.

Cultivations.—Winter barley requires much the same soil preparation as already described for winter wheat. It will not usually follow roots because these are not removed in time for autumn sowing; following a straw crop it needs the same cleaning and the same roughness of tilth as wheat planted at a similar date.

For spring-sown barley a fine, even tilth is required in order to obtain a rapid, even germination over the whole field. Since the tendency is towards very early sowing of spring barley, deep ploughing is inadvisable in most cases, and may be disastrous when sheep are on the root land till late in the spring.

On stiff land, where sheeping-off is not practised, or where barley follows a cereal, the best procedure is to plough early and let the furrow weather down naturally during winter and early spring. It is undesirable

to hurry the preparation of the seed-bed, and it is essential that implements be kept off the land until the subsoil has dried out sufficiently. Much heavy land will break down to a "sugar mould" after frosts, or after alternate wetting and drying in spring, and little cultivation is required. It is imperative that such land should be left unworked as long as possible, and that it be drilled immediately cultivations have finished; wet weather at this critical stage may completely ruin the tilth, hence the need for rapid work in planting the seed.

Manuring.—The manuring of the barley crop is a controversial matter, but one thing is quite certain—barley will not succeed on a soil which is short of lime. Barley is one of our most lime-sensitive crops, and to attempt the production of a malting sample on a sour soil is to essay the impossible. If there is any doubt at all about the lime status of the soil, a test should be made and expert advice obtained as to the desirability of postponing the planting of barley until lime can be thoroughly incorporated into the land.

It is well known that the yield of barley grain can be increased very considerably by the application of nitrogenous manures, and for a crop of feeding barley sulphate of ammonia or nitro chalk can be profitably employed in excess of 1 to 1½ cwt. per acre. But nitrogenous fertilisers have two serious disadvantages where malting samples of grain are aimed at; they may increase the percentage of nitrogen in the grain and they may cause the crop to lodge. The farmer himself must use his knowledge of the fertility of his land and decide what he is to do. After folded roots it is often unnecessary and undesirable to use any fertilisers whatever.

If barley is a second straw crop on land in poor condition, a complete fertiliser dressing may be desirable, say 1 cwt. sulphate of ammonia, 2 to 3 cwt. superphosphate and 1 cwt. muriate of potash per acre. Superphosphate certainly has a good effect upon root development and grain formation, but very heavy applications are not profitable. On light chalky soils potash may be essential, as experience during the 1939-45 war very definitely proved. Light sandstone soils, too, may benefit from additional potash.

Winter-planted barleys are more likely to need nitrogen than spring-planted barleys, and this element is best applied as a top dressing in spring, though phosphates and potash should be put into the seed-bed.

If the combine drill is used for sowing barley the fertilisers used should be of the granular type. Powdered fertilisers do not sow perfectly evenly, and there is evidence that unevenness in the crop may be caused by this irregularity of distribution through a combine drill. The problem does not arise where powdered fertilisers are broadcast before the seed is planted.

Sowing.—There is a general tendency towards the earlier planting of spring barley, for experiments and experience have shown the profitability of early planting. Drilling begins in February in the south,

and continues until April in the later districts. The habit of using winter varieties is spreading, for an early harvest can be obtained from autumn-planted barley. Although in some seasons Spratt Archer planted in autumn or in December can survive the winter, this barley is not truly winter-hardy, and it is better to rely upon the truly hardy varieties, such as Pioneer and Prefect. Autumn planting has, of course, the attraction of reducing work at the spring rush period.

Barley should be drilled at about 1 to 1½ inches deep, and should be harrowed and rolled immediately. Deep drilling leads to an irregular establishment and consequently to irregular ripening. The importance of a fine tilth resting on a firm bottom is obvious.

Rate of seeding is about 1½ cwt. per acre. This may be increased slightly in northern districts.

Seed should be dressed with a mercuric dust to prevent "stripe" caused by Helminthosporium and also Covered Smut.

After Cultivations.—Barley on light land will stand quite a lot of harrowing and the seedlings of annual weeds, especially spurrey, can be destroyed in large numbers by this surface cultivation.

Harvesting.—Barley intended for malting purposes must be dead ripe before it is cut. The straw at this stage should show no trace of green colour, and the grains should be hard, with a finely wrinkled skin. The use of the combine harvester has shown that barley can often be left appreciably longer before cutting with advantage to the sample.

Barley cut with the binder when properly ripe does not need to stand long in the stook unless there is a lot of rubbish in the butts of the sheaves. The crop can be threshed direct from the field, but the more usual plan is to rick it and allow the barley to "sweat" before threshing. Barley must be quite dry before it is carried, and it is desirable to thatch the rick immediately to keep out rain, which may damage and discolour the grain.

In threshing, great care is necessary, otherwise much of the labour expended on the crop may be lost because of damage to the grain. Neither the concave nor the hummeller should be set too close, or some of the grains may be cracked and the awn broken off too close. These are very bad faults, which ruin the grain for malting. The grain must be properly screened, so that the sample is plump and uniform, with no thin or cracked grains.

Combine harvesters are being increasingly used in the harvesting of malting barley, despite the opposition of some maltsters who refuse to buy barley which has been dried on the farm. These buyers, of course, fear that the unskilful use of a farm drier may lower the germination of the grain.

Yield.—The average yield of barley is about 16 cwt. of grain and 16 cwt. of straw per acre. Good crops may yield up to 25 and even 30 cwt. of grain.

OATS

The oat crop in many districts is of far greater importance than either barley or wheat, for in addition to providing a useful grain food for human and animal consumption it supplies a valuable fodder in its straw.

Soil and Climate.—Oats will succeed on a great variety of soils, and in very diverse climates, provided the crop is kept supplied with plenty of moisture. For example, in the north and west, where the rainfall is abundant, good crops can be obtained from quite light land; in the dry climate of the eastern counties excellent yields are obtained from the peaty soil of the fen areas, which provide plenty of moisture from below. But without moisture the oat cannot thrive, and on dry soils in dry areas barley (or rye) is more profitable. Oats, too, do not require the same degree of warmth as other cereals, and consequently assume an increasing importance in the hilly districts as one goes north and west. Generally speaking, oats are most widely grown on the light to medium heavy soils because of the difficulty of getting a good tilth early in spring on the really heavy clays.

Varieties.—There is a very large number of different varieties of oats, as might be expected from the very diverse conditions in which the crop is grown. Most varieties are for spring sowing, but a few are winter-hardy, at least in normal years in the south and midland areas of the country. It used to be customary to divide oats into grain-producing and straw-producing varieties, according to the relative amounts of grain and straw yielded. Most of the modern oats are grain-producers; the older varieties give good yields of straw and only moderate yields of grain, and are typified by the Potato oat, Clemrothery and Tam Finlay. In some parts of the country a straw-producing oat may be a better proposition than a variety having a high grain-yielding capacity, but a thick reedy straw of lower palatability and feeding value. The characteristics of the chief varieties of oat are summarised in the accompanying tables.

Varieties of Oats

Variety	Colour of Grain	Straw length and strength	Remarks
1.—Winter Oats			
S. 147	White	Medium: very good	A good yielder on fertile soils.
S. 172	White	Short: excellent	For very fertile soils only.
S. 81	White	Medium: moderate	Yield and standing capacity inferior to S. 147. Resistant to eelworm.
Picton	White	Medium: very good	A good yielder on fertile soils.
Grey Winter	Grey	Long: poor	Very hardy and reliable cropper. Both thin-husked grain and straw of good quality. Liable to lodge.
Black Winter	Black	Long: weak	Not quite so hardy as Grey Winter.
Unique	White	Long: weak	Similar to Grey Winter but earlier ripening.

Variety	Colour of Grain	Straw length and strength	Remarks
		2.—Spring Oats	
Victory	White	Medium: good	Reliable, good quality oat for average fertility.
Eagle	White	Medium: very good	Good yielder on good soil; grain small, thin husk.
Star	White	Medium: very good	Good yielder; should replace Victory on fertile land.
Onward	White	Medium: very good	One of the most profitable varieties. Early ripener.
Golden Rain	Yellow	Medium: very good	Grain small but of good quality. Early ripening.
Resistance	White	Short: very good	For very fertile land; must be sown before March.
Marvellous	White	Medium: excellent	For very fertile soils; grain and straw coarse. Sow before end of February. Ripens early.
Supreme	Black	Short: very good	Early ripener.
Early Miller	White	Medium: very good	Good variety for late and high rainfall districts. Yield moderate.
S. 84	White	Medium: very good	Husk rather high. For late and high rainfall districts.

Cultivations.—In general, the preparation of the ground for winter oats is similar to that already described for winter wheat, and for spring oats the workings are much the same as for spring wheat. Because winter oats do best when sown early in autumn, the preparation of the oat ground should precede that for winter wheat.

It is very desirable, also, to plant spring oats as early as possible, not only because better yields are obtained that way, but also because the risk of damage by Frit fly is much reduced if the plants get away to an early start. Where spring oats follow a ley it is very desirable to plough the ley as soon as possible to prevent over-wintering of the larvæ of the Frit fly on exposed ryegrass plants. If, however, the ley is ploughed very early, a second ploughing may be necessary to rebury any herbage which may spring up in the seams between the furrows.

Manuring.—Oats are very liable to lodge, and the farmer must strike a balance between a heavy crop which may be very expensive to harvest, and a lighter crop which is upstanding, and which can be harvested cheaply, easily, and with its straw in good condition. On very good, old turf it may frequently be desirable to substitute wheat or beans, delaying the planting of oats for a year to prevent loss through lodging. On turf of moderate fertility oats should need no fertiliser at all; often two successive crops of oats can be taken without fertiliser. When oats follow a well-dunged crop of roots no added manure should be necessary. Oats which follow wheat or beans on old ploughland will benefit from

phosphates (2 to 3 cwt. per acre of superphosphate) and there is experimental evidence to show that a *late* application of nitrogen (1 cwt. per acre sulphate of ammonia) significantly increases the yield of grain without greatly increasing the risk of lodging. So much, however, depends upon climatic conditions, that it is unwise to dogmatise upon the manuring of oats. The danger of lodging is greatest in a wet district, and it is a matter of experience to decide whether or not a top dressing is really economic. On land in poor heart a complete dressing of fertilisers may be desirable.

Sowing.—Winter oats do best when sown early; in many districts, on clay soils, planting in late September is ideal. After the end of October oat drilling becomes increasingly hazardous, and it is often preferable to postpone further planting until early spring. At one time it was thought that such oats as S.147 and S.172 could not be successfully sown once October was past, but early spring plantings of these varieties have given good results in many parts of the country. Marvellous is another oat which can be sown in autumn or spring, though it cannot be relied upon as a winter variety except in favoured localities and in mild winters.

Spring oats should be sown as soon as the land is in a fit condition, which usually is from the end of February onwards. March is the great month for oat planting, but the risk of damage by Frit fly increases with every week that planting is delayed after the end of that month.

There is more variation in the rate of seeding in oats than in other cereals because the size and weight of the seed are themselves very variable. Small-grained oats like Resistance and Eagle do not require the same weight of seed per acre as, for example, Marvellous and Victory. The extremes are, perhaps, represented by the 3 bushels per acre of Grey Winter sown in early October, and the 5 bushels per acre needed for Marvellous sown in early March.

Home saved seed is very often used, and it is scarcely necessary to say that short, plump grains are preferable to long, thin grains with a relatively small caryopsis and a high proportion of husk. If the sample cannot be dressed to a uniform size, the seed rate should be on the generous side.

Especially in the northern districts there has been in the past a considerable number of failures of oats due to Leaf Stripe and allied diseases. These troubles, as well as Smut diseases, can be almost completely prevented by dressing the seed before sowing with one of the organo-mercury powders.

After Cultivations.—Winter oats benefit from a rolling in spring to firm the plants and crush the clods. Oats have a more tender foliage than wheat and the plants are not so firmly fixed in the soil as wheat; harrowing must consequently be done with discretion, or a considerable reduction in yield may result. Spring grazing of winter oats, although not common as in the case of winter wheat, is sometimes practised.

Harvesting.—In the traditional oat-growing areas, oats are cut in what the East Anglian farmer would consider a very unripe condition. There are very sound reasons for this, and it could be argued that in much of the east and south of the country the cutting of oats is delayed too long. In northern and western districts the straw and the grain are of almost equal value, and by early cutting a straw of greater palatability and feeding value is obtained. If left till dead ripe a lot of grain may shatter out during harvesting operations. An early start with the oats gives more time for harvesting the other cereals.

Because oats are cut on the green side they have to stand in stook longer than wheat or barley. The old saying is that they should "hear the church bells ring three times"—that is, they must stand at least a fortnight before being ricked. In wet districts where oats are the main cereal, considerable pains are taken to harvest the crop in good condition. The stooks are covered by a sheaf "hooded" on top to throw off the rain, and the stacks are made very small, often with a tripod or other arrangement in the middle to ensure proper ventilation and reduce the possibility of heating.

Yield.—The average yield is 15 cwt. per acre of grain, and 20 to 25 cwt. of straw. A yield of 20 to 25 cwt. of grain would be considered satisfactory, and 30 cwt. would be reckoned a good crop. Up to 2 to 2½ tons of straw would be expected from the heavier crop.

RYE

Rye is a grain crop of small importance in England and Wales, and is practically unknown in Scotland. Only in time of war is the crop grown at a l extensively; before the first World War the acreage under rye in England and Wales was about 50,000 acres, and this increased to just over 100,000 acres in 1918 and 1919, only to drop to 18,000 acres in 1938. In 1943 a peak acreage of 123,000 acres was reached, but in 1946 the area had again dropped to 55,000 acres.

The reason for this fluctuation is that in normal times, on average land, rye leaves less profit than other crops. Rye will grow on soils which are too acid, too light and too poor to support paying crops of the other cereals, but the amount of marginal land of this sort kept under cultivation is very small, and consequently so is the acreage under rye. Rye will give good yields of grain when grown under fertile conditions, but the other cereals do better still, and so rye is pushed out to the soils of lowest fertility. There is a small special market for rye grain in the manufacture of "crisp-breads" or rye biscuits.

For poor, dry, sandy or chalky soils in areas of low rainfall rye is the safest cereal to plant.

Much of the rye which is planted is used as green fodder; in 1937 almost one-third of the rye acreage was used for grazing.

Varieties.—Unlike the other cereals, rye is cross-fertile, and natural crossing in the field makes it difficult to maintain the purity of a variety. Consequently, with rye there do not exist the numerous named varieties so characteristic of wheat, barley and oats. Most of the rye sold for seed in this country is labelled "rye," "winter rye" or "giant rye," without any attempt to specify a varietal name, and it is probable that these stocks are mixed; these are winter ryes. King II is a new short-strawed variety.

For spring planting St. John's Day, or Midsummer rye is used; a grain crop is not taken from these sowings as a rule, though occasionally the plants are allowed to run up to head after a green crop has been taken in autumn and another in early spring.

Trouble is sometimes experienced if a winter rye is sown in early spring; the plants refuse to form ears properly and the crop may have to be grazed or ploughed in instead of being harvested for grain.

Cultivations.—These are similar to those already described for winter wheat.

Manuring.—Very little experimental work has been done in this country on the manuring of rye. At the Tunstall Experimental Station in Suffolk no response to phosphates and potash was obtained, but $1\frac{1}{2}$ cwt. per acre of nitrate of soda doubled the yield. On the other hand, Continental experiments have demonstrated an increase of from 30 to 40 per cent. from applications of $2\frac{1}{2}$ to 4 cwt. per acre of superphosphate.

Sowing.—For grain, rye should be sown early in the autumn, i.e. September or early October. If the plant is very strong it may be grazed lightly before the onset of frosty weather. For early sowings 2 to $2\frac{1}{2}$ bushels (1 to $1\frac{1}{4}$ cwt.) and for late sowings 3 bushels ($1\frac{1}{2}$ cwt.) per acre are the usual rates. Spring seedings are not recommended for grain production.

After Cultivations.—Rye is frequently grazed in the spring, and provided this is done early and not too severely the following grain crop should not suffer. If, however, the plants are bared down to the ground late in spring, especially if the weather turns dry, the yield of grain is likely to suffer. In a droughty spring a farmer, whose primary business is milk production, may find it more profitable to turn the rye into milk than grain.

Harvesting.—Rye is the first straw crop to ripen and may be ready ten to fourteen days earlier than wheat. The grain matures slowly compared with the straw, which is consequently dead ripe by the time the grain is hard enough to harvest. Although rye straw is very long, it is usually dealt with quite satisfactorily by the binder.

Yield.—The average yield of grain per acre is about $12\frac{1}{2}$ cwt. and of straw 30 to 40 cwt. The straw, in peacetime, was sometimes more profitable than the grain; it is very elastic, making good thatching and packing material. For feeding purposes it is practically useless.

BEANS

Beans are leguminous plants, having the characteristic flower and the protein-rich seed of the *Leguminosæ*. They also have on their roots the bacterial nodules which enable the plant to accumulate nitrogen from the air, and which enrich the soil with organic nitrogen when the stubble is ploughed under.

Beans are always associated in the farming mind with stiff clay soils and, indeed, they are one of the few farm crops which will grow satisfactorily on heavy, sticky land. There is no doubt that beans proved a "sorry" crop in many parts of the country during, and immediately after, the war; some beans were ploughed under long before harvest, while many other crops which were actually gathered yielded less than 10 cwt. per acre of threshed grain. To some extent fungus diseases such as Chocolate Spot and Botrytis were responsible for these poor results, but poor cultural methods and manurial treatments also played their part. Good crops of beans, yielding up to 30 cwt. per acre, were grown during these same years in various parts of the country.

Although beans are traditionally associated with strong clays, they will grow satisfactorily on medium loams if well manured. They do not succeed on light land, nor on any land which is short of lime. On badly drained, heavy land, success with winter beans is unlikely.

Varieties.—There are two main classes of field beans, namely winter beans and spring beans. Winter beans are sown chiefly in the southern half of the country, for they are not sufficiently hardy to survive the average north-country winter. Winter beans are frequently planted in the spring on farms in the Midlands. There are no well-known varieties of winter bean, for the plants cross freely and the maintenance of pure stocks is more difficult than it is with the cereals. Spring beans include the Scotch horse bean (also known as Carse or Kilbride) and the English horse bean or Tick bean, which has a small, almost spherical seed. These are the typical field beans, but occasionally there are planted varieties which approach the garden or broad bean in type, such as Mazagan and Fortyfold. These have larger, flatter seeds, and are more delicate in growth.

Place in Rotation.—Years ago a common rotation on heavy land was Wheat: Beans: Fallow. This has long been too expensive, and in the four-course shift it is common for beans to take part of the clover break. Beans commonly follow a white straw crop, especially where it is customary to hoe the beans, which then behave to some extent as a cleaning crop. Beans make a good first crop on newly broken-up old turf which is known to be badly infested with wireworm, as the plant is not so liable to serious attack as the cereals, though severe losses from wireworm attack have been reported. It is not usual to grow two bean crops in succession.

Beans make quite a good nurse crop for grass and clover seeds, but

there is a widespread opinion among farmers that clovers sown *after* a bean crop do very badly. There is some support for this view so far as red clover is concerned, but not so much in regard to alsike and white clovers; the point requires careful investigation.

Manuring.—Both practice and experiment confirm that beans respond very well indeed to farmyard manure; the Saxmundham (Suffolk) experiments indicate a return of 3 bushels per acre for every ton of dung applied. If dung is not available there is special need for potash to be given to the crop—1 cwt. per acre of muriate is sufficient for most conditions. Phosphates also give good returns, and a suitable dressing is 3 to 5 cwt. of superphosphate or high-grade slag per acre. There is little or no response to nitrogenous manures.

Cultivations and Planting.—Beans do not need a fine tilth, and are very frequently ploughed in. This is a convenient practice on stiff land where, for example, beans follow wheat. Dung, if available, is spread on the stubble, and the beans are put into a small box drill attached to the plough; seed is dropped into every second or third furrow as ploughing proceeds, and planting can in this way be completed in good time before the onset of wet weather. Care must be taken not to bury the beans too deeply by this method of sowing, and the plough should be set at about 4 inches deep. A few farmers broadcast beans and then plough them in, but this is wasteful of space and is not recommended.

After a bare fallow, winter beans are usually drilled, and spring beans are also usually drilled on a stale furrow which has been allowed to weather during the winter. The width between the rows varies very considerably. Where it is intended to horse-hoe the crop, wide spacing—21 to 24 inches or even more—is essential, and these distances are sometimes adopted even when there is no intention of hoeing, because it is felt that the wide spaces give the plants a better chance of forming pods low down on the stem. Very much closer spacing in the rows is advocated by other growers, who argue that this keeps weeds in check.

The rate of seeding is about 2½ bushels (1½ cwt.) per acre for winter beans and three bushels (1¾ cwt.) for spring beans.

Winter beans are best sown during October; if sown too early the plants may become "nesh," or too soft to stand the winter, but if sown too late they may not braird early enough, especially on very wet land, and may rot. Spring beans should be sown as early in February as the state of the land will permit; late-sown beans do not yield well and become very liable to attack by aphis or black fly.

There is some evidence that beans yield more reliably when mixed with a cereal than when sown alone. Some farmers mix a few beans with their cereals; others plant about 1 cwt. of beans and, a few weeks later, 1 cwt. of oats. It is claimed that beans in such a mixture escape aphis attack. At threshing time the two seeds are easily separated.

After Cultivations.—Beans in wide-spaced rows are horse- or

tractor-hoed in spring when the top-soil and the subsoil are in suitable condition. Beans in narrower rows may be harrowed to kill weed seedlings. It has been suggested that harrowing should not be done in a mild, muggy spring unless the crop is very thick, or foul with weeds, because of the possibility of spreading fungus infection by damaging the haulm; it has yet to be proved that harrowing does, in fact, bring about this infection.

Harvesting.—Beans are ripe when the straw has turned almost completely black, the soft parts of the leaf have dropped off, and the hilum or eye of the seed is black. If left too long the pods will shatter during harvesting. If podding has taken place well down the straw it is particularly necessary to set the binder to cut as low as possible; beans are hard on both knives and canvases.

The crop must not be stacked until the straw in the middle of the sheaves is dry, because of the danger of moulds developing. For the same reason immediate thatching is desirable. Beans are usually not threshed until spring, for the fresh seed is unsuitable for stock.

Yield.—The average yield is about 16 cwt., but a ton per acre would be looked upon as quite satisfactory. The weight of straw per acre is from 20 to 30 cwt.

PEAS

Field peas for stock feeding are not a very popular crop owing to the uncertainty of the crop, the very narrow range of soils to which it is really well adapted, and the difficulty of harvesting.

Soil and Climate.—At one time peas were recommended as a crop for light land, but experience has shown that, except in moist climates, this is a mistake. They do better on medium loams in not too high a state of fertility; on very fertile land peas run too much to straw, and the yield of grain is low. On heavy land, especially if the weather is wet, failures may occur from the general unhealthiness of the plants. On very light soils peas are not a success.

Peas are a dirty crop, for they do not compete well with weeds. Land intended for peas should consequently be as weed-free as possible.

Peas can follow any crop, but as often as not they come after a cereal. If they follow roots or potatoes they have the advantage of clean land, but if the previous crop was very heavily manured there is the possibility of an excessive amount of haulm and a disappointing weight of grain.

Varieties.—There are two main types of field peas—Grey or Dun peas and Maple peas. There is, however, much confusion in the classification of peas.

Grey or Dun peas take their name from the colour of the seed. As a class they are early ripeners, with a medium length of straw, but there is considerable variation in these two characteristics. Early Minter (also called Norfolk Dun) and Early Warwick are varieties in this group.

Maple peas have lightish brown seeds speckled with whitish or yellowish spots, and the eye or hilum is either black or light in colour. The name Partridge peas is given to early-ripening types of maple pea having a light-coloured eye. The seed is sometimes called Pigeon pea, because it is favoured on account of its small size by pigeon fanciers. The haulm of Maple peas is longer than that of Dun peas.

Marathon is a dark-eyed maple pea bred at Cambridge, giving good yields of grain or green forage.

Black-eyed Susan (Jessie's or Sweet Jessie) is a variety with a black hilum and reddish-coloured seed confined to the Eastern Counties.

Prussian Blue, Harrison's Glory, Lincoln, and many other varieties are garden peas grown for special purposes.

Cultivations and Sowing.—Peas are sown in spring, preferably on stale land which was ploughed before Christmas and allowed to weather down. A very fine tilth is unnecessary and undesirable.

Early sowing, provided the soil is in the right condition, is desirable. It may begin in early February and continue until the end of March. Drilling in 9-inch rows is customary, to a depth of about 2 inches. The quantity of seed used per acre varies with the variety, the limits being $2\frac{1}{2}$ to 4 bushels ($1\frac{1}{2}$ to $2\frac{1}{4}$ cwt.) per acre, with an average of about 3 bushels ($1\frac{3}{4}$ cwt.). Seed should be pre-dressed with an organic mercury dressing.

Manuring.—Peas will not succeed in an acid soil and should not be planted in lime-deficient land. They should be manured with caution because of their tendency to run to excessive straw on fertile soils. After well-manured sugar beet or potatoes the land is too rich for successful crops of field peas. Added nitrogen is to be avoided, but phosphates and potash on the less fertile soils have given responses. After a well-manured cereal such as wheat, peas should do well without additional fertiliser.

Harvesting.—To avoid excessive loss through "shelling," or splitting of the pods, peas must be harvested as soon as the seeds are well formed and firm, but before the pods are dry and brittle. The haulm by this time is yellow, and most of the pods turned yellowish-brown, but they should still be tough, not brittle.

Small areas of peas are still cut by hand by scythe or bagging hook, and at once put together in small heaps or wads, which are repeatedly turned. Larger areas are cut by the grass mower, by the old-fashioned sail reaper, or by the reaper-binder with the binding mechanism out of action. A special windrowing attachment on the mower can be used to throw the swath clear of the next cuts. Lifters on the fingers, and other special attachments can be used to raise the crop on to the knife. An alternative and quite efficient method is to pull out the peas with a hay rake or with a "toppler," which is a kind of small reversible sweep, common in the Eastern Counties.

Peas are very liable to go mouldy, and constant turning of the wads

or heaps is essential, especially in "dabbling" weather. If the pods become really wet, premature sprouting of the seed may occur. The use of tripods renders harvesting more certain, and actually may be less laborious than traditional methods. Threshing must be done carefully to avoid splitting the seed, and the work is hard because of the way the crop packs down in the rick.

Yield.—The yield of peas is very uncertain, with an average for the country of about 14 cwt.; a ton of seed per acre would be looked upon as very satisfactory. The yield of straw is from 20 to 25 cwt. per acre.

The straw is a useful fodder, relatively rich in nitrogen.

VETCHES OR TARES

Vetches or tares, which are closely related to the field bean, are grown both for their seeds and as a forage crop. They do well on most soils provided there is a sufficiency of lime and the usual fertilising elements.

Varieties.—From a practical point of view there are only two kinds of vetches, spring vetches and winter vetches, though a third might be added—the Goar (Gore) or summer vetch. It is not possible to distinguish the seeds and plants of spring vetches from those of winter vetches; the difference is one of hardiness.

Uses.—Vetches are cultivated for three main purposes: (1) for seed; (2) for green fodder and silage; (3) for hay.

(1) When grown for seed vetches can be sown alone at the rate of about $2\frac{1}{2}$ bushels ($1\frac{1}{4}$ cwt.) per acre, but as the plants are very liable to collapse, it is customary in many districts to add some beans to support the vetches. The two grains can be separated after threshing. The yield of vetch seed should be not less than 12 cwt. per acre.

(2) For fodder and silage purposes it is usual to mix vetches with a cereal and sometimes with beans and peas as well. At one time it was recommended to sow, at least on light land in autumn, up to $1\frac{1}{4}$ cwt. of vetches and $\frac{1}{2}$ cwt. rye or oats per acre. The tendency now, however, is to reduce the quantity of vetches, sowing as a rule not more than 56 lb. and usually only 28 lb. vetches with the cereal. A common mixture is $\frac{1}{4}$ cwt. vetches and $1\frac{1}{4}$ cwt. oats. For silage purposes, Carr suggests for winter planting in northern districts 80 lb. rye, 28 lb. winter vetches, 20 lb. Italian ryegrass; or 56 lb. winter oats, 56 lb. winter barley, 28 lb. winter vetches, 20 lb. Italian ryegrass. These mixtures should provide at least two cuts of green fodder. For spring planting, Carr suggests $1\frac{1}{4}$ cwt. oats, 14 lb. vetches, 10 lb. maple peas and 14 lb. Italian ryegrass.

(3) For hay, mixtures of vetches and oats can be used, but the curing of such mixtures is a lengthy business and generally speaking peas are a better plant than vetches for this purpose. If intended for hay, vetches should be cut while flowering; if left till the pods are well formed the hay becomes tough and loses its palatability and feeding value.

Cultivation and Planting.—Although vetches do best on well-cultivated ground, they will grow quite well with less workings. Winter vetches, for example, may be sown in a stubble that has merely been thoroughly disc-harrowed. Vetches can also be broadcast on the ploughed furrow and harrowed in. The usual method is to drill, and despite the size of the seed, deep planting is not recommended, a depth of about 1 inch being sufficient.

Winter vetches are best sown early, in September on the heavier soils if possible. Spring vetches should be planted as soon in February as possible, though for fodder purposes a succession of sowings may be made.

Nitrogenous fertilisers are not recommended for crops consisting largely of vetches, but as with most leguminous crops, a dressing of phosphates is beneficial, with potash on the lighter soils.

POTATOES

Potatoes form one of the most important arable land crops in these islands, and they are capable of producing more human food per acre than any other plant. Although the plant will grow well and yield heavily in many types of soil, practical difficulties at lifting time confine the crop to the lighter types of land. Quality, a very elusive condition, is determined by soil type to a very much greater degree in potatoes than in any other farm crop. It is generally conceded that the best eating potatoes come from limestone soils, while tubers raised in black soils (fen type) are definitely inferior in quality and appearance. Tubers from alluvial soils and sandy loams fetch good prices; those from skirtland soils (those in which the alluvial soils merge into the black soils) are also popular. Potatoes from "red soils" are favoured by many potato merchants: exactly what a red soil is in this connection cannot be defined very accurately. Many of the light sandstones of the Bunter and Keuper Sandstone formations admirably suited to the crop are distinctly red, but so are the stiff Keuper Marls and Old Red Sandstones which cannot be looked upon as typical potato soils.

Deep, light land, easily worked, and with no tendency to stick to the implements of cultivation and harvesting, is required for successful potato growing. Potatoes are able to yield well in land too short of lime for most other crops except rye and oats, which in special conditions—such as the reclamation of bracken-covered land—is a valuable advantage.

Varieties.—Potatoes are classified according to (1) the time of ripening, (2) their resistance or susceptibility to Wart Disease. Wart Disease is a notifiable disease of the tubers caused by a soil fungus, which is present in some areas and not in others.

With regard to time of ripening—or more accurately harvesting—it is customary to recognise three (or possibly four) classes of potatoes: First

Early, Second Early and Maincrop. Maincrop varieties may be further divided into Early Maincrop and Late Maincrop potatoes. This is not a hard and fast classification, because some growers may call a certain variety a second early, while others may speak of it as an early maincrop. The number of potato varieties is legion, but most of the potato acreage is planted with only a few very popular sorts. The more important varieties are set out below, the date of their introduction being given in brackets.

First Early

Epicure (1897).—Non-immune. A slightly flattened, round to oblong white-fleshed tuber with deep eyes and rather coarse appearance. Hardy, and recovers well from frost. It is very early and yields heavy crops. Is popular in Lancashire and other districts but not grown much in Lincolnshire.

Arran Pilot (1930).—Immune. A white-fleshed kidney variety with shallow eyes, good appearance and moderate cooking quality. Liable to contamination from most virus diseases. An excellent cropper which has become extremely popular in many districts during the last ten years.

Sharpe's Express (1900).—Non-immune. A white-fleshed kidney of first-class quality and appearance requiring first-class soil to give good crops. Has been largely superseded by Arran Pilot.

Second Early

Eclipse (or Sir John Llewelyn) (1897).—Non-immune. A white-fleshed tuber with very shallow eyes. In shape the tuber is variable, one type being a pointed kidney, the other more rounded. Quality good. This variety crops very well and is the most widely-grown second early.

Dunbar Rover (1936).—Immune. A shallow-eyed oval tuber with white flesh. Quality extremely good, dry and floury, yield moderate to good.

Great Scot (1909).—Immune. A white-fleshed, round tuber in which the eyes are sometimes rather deep. Good quality, long keeping, but has a tendency to become hollow in the centre. Is sometimes classed as an early maincrop.

Early Maincrop

Arran Banner (1927).—Immune. Tuber shallow-eyed, round, white-fleshed. Cooking quality medium to good, yield very good. This variety, when grown on very fertile or heavily manured soils, is liable to form enormous tubers which become hollow and watery in the centre. It should be planted in the less fertile potato lands, or should be planted at close intervals and lifted before it is mature.

Majestic (1911).—Immune. A kidney-shaped tuber with white flesh and very shallow eyes. Quality fairly good and stores well. A good cropper. This is the most widely grown maincrop potato in England, but is not popular in Ireland or Scotland.

King Edward VII (1902).—Non-immune. Tuber an oval kidney, the flesh white but the skin characteristically flushed with pink. Very susceptible to Blight. Quality good but cropping capacity poor. This variety is much sought-after by consumers in England and it always sells well when white-

skinned potatoes are a dragging market. It is not popular in Scotland or Ireland. Red King is a selection from King Edward in which the tubers are almost wholly pink.

Gladstone (1933).—Immune. Tuber resembles King Edward, but is more round and has rather more pink coloration. Quality very good and yield larger than King Edward. Is becoming popular as an immune substitute for King Edward, its tubers having the same popular appeal.

Late Maincrop

Arran Peak (1937).—Immune. An oval tuber with medium deep eyes, white flesh and a yellow-netted skin. More than average resistance to Blight. Yield and quality good, and stores well. This variety is becoming popular in many districts.

Kerr's Pink (1907).—Immune. Tuber round and frequently rather ugly, with medium to deep eyes. Flesh white, skin pink. A heavy cropper and quality good, but after a tremendous burst of popularity from 1930-35 it is now less widely grown.

Dunbar Standard (1936).—Immune. Tuber a long oval, white-fleshed, shallow-eyed, good appearance. Quality good, stores well, yield good. Both this variety and Kerr's Pink ripen very late, which in some districts is a distinct disadvantage.

Choice of "Seed."—With no other crop is the right choice of seed so important as it is with the potato. The principal diseases carried by seed potatoes are virus diseases such as Leaf Roll, Mosaic, etc., and these give no external symptoms of their presence. Virus diseases very seriously reduce potato yields, and every effort should be made to obtain virus-free seed. Since most virus diseases are spread by aphides, and since in certain parts of Scotland, Northern Ireland, Isle of Man, Eire, Wales, and the northern counties of England there are areas relatively aphis-free, the cleanest seed comes from these areas. To assist growers to obtain virus-free seed special certification schemes are operated by the responsible authorities in the various countries concerned. For their own security growers should demand certified stocks. There is a choice of three grades of certified seed:

(1) "S.S." certificates are issued for stocks intended for growing-on for seed production. The minimum standards are 99·95 per cent. purity as to variety, and almost complete absence of virus disease.

(2) "A" certificates are issued for high grade commercial seed which is 99·5 per cent. pure as to variety, and 99 per cent. free from visible virus infection.

(3) "H" certificates apply to reliable commercial seed 99·5 per cent. pure and 97 to 98 per cent. free from visible virus infection.

The grade of the certificate is followed by letters indicating the country of origin of the seed as follows: (Scot.) for Scotland; (Nor. Ir.) for Northern Ireland; (E) for England; (W) for Wales; (I.O.M.) for Isle of Man; (Eire) for Eire. The letters N.I. are added in the case of

varieties not immune from wart disease. Each stock is given a number which enables it to be traced to the farm on which it was grown, and a number indicating the year of origin. A certificate numbered thus: A (Nor. Ir.) 8910/46, indicates an "A" grade stock grown in Northern Ireland in 1946. If the variety were a non-immune one the certificate would read: A (Nor.Ir.) N.I. 8910/46.

Generally speaking, it is always advisable to plant nothing but certified seed. Some growers use "once grown" seed, which are potatoes grown in England or Wales from parent stocks which were certified by any of the countries mentioned above. They are classed as "uncertified (English once grown)" or "uncertified (Welsh once grown)," but they carry no guarantee as to purity and freedom from virus disease. No other class of seed potato than certified should ever be bought—the risk of severe loss from virus diseases is too great.

Although the presence of potato eelworm, bolters, blackleg, etc. is taken into account before certificates are issued, the certificate does not cover freedom from blight, dry rot or other tuber diseases.

The size of seed potatoes is of some importance; very small seed must be planted very close to give a good yield, but the proportion of ware tubers in the crop is high. Some farmers plant nothing but chatt potatoes from certified stocks, maintaining that this is the most economical method. Large seed is expensive because so much is required per acre, and the proportion of seed-sized tubers in the crop is high. In general, seed potatoes are those which are retained by a 1¼ inch-riddle, after passing a 2¼-inch riddle. The size of the riddles used must be stated by the vendor of seed potatoes.

Sprouting Seed.—For early potato crops it is essential to use sprouted seed, and for maincrops the use of sprouted seed is a paying proposition if the chitting or sprouting can be economically managed. Lofts and barns can be used for sprouting seed potatoes provided there is enough light and sufficient protection from frost. The seed potatoes, immediately after lifting, are put into shallow trays or boxes which can be piled one on top of the other with a space in between each tray to admit light. Each tray holds about 28 lb. of seed. In such conditions the tubers produce short, sturdy, dark-green sprouts about 1½ inches long. Specially heated chitting houses are used on the big potato farms.

Cutting Seed.—Some seasons the available seed may be very large, and the possibility of cutting it must be considered. To obtain successful results from cut seed two principles must be observed: (1) the tuber must be cut from heel end to rose end (i.e. longitudinally) so as to equalise the distribution of buds or eyes (2) the cut tubers must be protected from sun and drying winds until the cut surface has healed over with callus if there is any delay between time of cutting and planting. If these precautions are observed, even such a "shy" variety as Majestic can give good results from cut seed.

Place in Rotation.—Potatoes are gross feeders and require plenty of plant food and organic matter if they are to give big returns. For this reason they make an excellent first crop when old turf and long leys are broken up, though wireworm may sometimes cause damage. In short rotations such as the four-course, where mucking the one-year ley is traditional, it is becoming increasingly popular to take potatoes instead of wheat after the ley. Wheat then follows potatoes without any further manuring. Often the aftermath following the hay crop is allowed to grow up without being grazed, and is ploughed in. Potatoes do well after most leguminous crops—clover, beans, peas, vetches. They do well after sugar beet, and vice versa. Potatoes, however, should not be grown too frequently in the same field for fear of eelworm attack. Large areas in Lincolnshire and other potato-raising districts which have been very heavily and frequently cropped with potatoes are now unable to grow profitable crops because of this parasite.

Cultivations.—The potato likes a soil which is deeply worked, and on strongish land a deep ploughing in September and October is desirable, after which nothing more should be attempted till spring. Subsoiling, if necessary, should be done in autumn, and any farmyard manure available should also be turned in then. In spring, as soon as the subsoil is dry (and on strong land this is most important) the ground is deeply cultivated or dragged, not ploughed, to keep the frost mould on the surface. It is then worked with harrows until judged suitable for planting. On the lighter soils spring ploughings are commonly practised: some growers with a stubble that contains couch grass or twitch will deep-plough with a one-way plough, putting the weed well out of sight, with every expectation that it will perish from such treatment.

Manuring.—At one time it was a common practice to apply farmyard manure in the ridges, but this is now less widely adopted for two reasons. The additional work of distributing the manure comes at a very busy time of year, and the necessary carting unduly consolidates the bottom of the ridges. Consequently, when dung is available it is usually ploughed in during the previous autumn. Only moderate dressings are desirable, say 12 to 15 tons per acre, provided there is a generous supplement of balanced fertilisers.

Potatoes pay well for their fertilisers. Nitrogen gives very good responses provided it is balanced with phosphates and potash. It appears from Crowther and Yates' review of experimental work on the manuring of potatoes that the chief faults in the past have been insufficient provision of nitrogen, and too much liberality with phosphates. Average potato land that has been dunged for potatoes should receive a dressing of fertilisers on the following lines:

Sulphate of Ammonia	2½-4 cwt. per acre
Superphosphate	3-4 „ „ „
Muriate of Potash	1-2 „ „ „

On land which does not receive dung these quantities can be increased by about one-third.

Fen soils require rather different treatment. The response is less to nitrogen, but is greater to phosphates. Up to 8 cwt. per acre of superphosphate may be given, while the sulphate of ammonia is reduced to 2 cwt. On silt soils considerably higher dressings than those suggested for average soils can be used with profit. In fact there is no other crop which pays so handsomely as potatoes for generous manuring, and responses to fertilisers are probably higher on the rich potato soils than on the poorer soils.

Sulphate of potash is commonly regarded as a better material for producing high-quality potatoes than muriate of potash, though critical evidence is lacking on the point. Since sulphate of potash is likely to be scarce for some years, muriate of potash will in any case have to be used.

Fertilisers are best broadcast over the open ridges just before the potatoes are planted.

Planting.—The thoroughly worked soil is cast up into ridges 26 inches apart and the setts are planted 12 to 14 inches apart, according to variety, in the bottom of the ridges. Early potatoes are planted much closer than maincrop. Planting is usually done by hand. Skilled workers in the potato-growing districts will plant an acre in an eight-hour day; sprouted seed must be placed, not dropped, and the rate of planting is reduced to about two-fifths of an acre per man-day. A gang of ten women, with one man to serve with seed, will keep a three-row coverer going. As soon as the tubers have been planted the ridges are split back to cover the seed. The average weight of seed required per acre is about 20 cwt.

To reduce labour costs and speed up the operation, special potato planters are being increasingly used. There is a great variety of design, varying from simple sledges to complicated machines which open a furrow, drop the seed, deposit fertiliser in bands on either side of the tuber, and close the furrow all in one continuous operation. Many of these machines are expensive and the grower must decide for himself which pattern, if any, will suit his purpose. These machines usually plant on the flat, and some growers like to ridge up immediately after the passage of the machine, though certain of the devices do themselves leave a shallow ridge.

In favoured districts, early potatoes may be planted as early as the end of February. Most maincrop potatoes go into the ground during April, but planting in May is not uncommon.

After Cultivation.—Within a week or ten days after planting the ridges should be harrowed down to destroy weed seedlings and inter-row cultivations begun to scuffle the soil to a depth of several inches. The ridges may be run up again and later harrowed down, and inter-row scuffling repeated. Or the scuffling may be continued until it is necessary to give the final earthing up. The amount of working to be given will depend upon soil and weather conditions, and the labour available.

A hand-hoeing between the plants is beneficial to the crop quite apart from the destruction of weeds. The final earthing up should aim at producing a ridge which is narrow and pointed at the apex, for this prevents to some extent the contamination of the tubers by spores of the blight fungus.

Spraying.—Early potatoes are usually not sprayed, as they are lifted before potato blight is prevalent. In many areas, such as the northern and south-western counties, blight occurs with such regularity that routine spraying or dusting with a copper-containing fungicide is essential if a satisfactory crop is to be obtained. In some midland and eastern counties, blight generally occurs late in the growing season and spraying is regarded as uneconomic, except possibly for such varieties as King Edward, which are very susceptible. Information on the use of sprays and dusts is given in Vol. 2, chapter 5.

Harvesting.—Early potatoes are lifted as soon as a paying crop has developed. The yield may be only two tons per acre or less, but the extra price obtainable for very early crops fully justifies the procedure. A difference of four or five days may tremendously affect the price received.

Maincrop potatoes should be lifted when the skin of the tuber has "set," that is, is not easily rubbed off with the finger. By this time the haulm will have turned brown and died away. Because of the rush of work in September and October the practice has developed of burning off the haulm with chemical substances to enable lifting to begin much earlier, since it is impossible to lift a heavy crop if the haulm is still green. It is now known that most of the infection of tubers by blight takes place at lifting time, for the spores shaken off the haulm (especially if it is still succulent) are scattered over the potatoes as they lie exposed on top of the ground.

The substances used for burning off the haulm destroy some of the spores and the partial destruction of tops means that fewer spores are present to be shaken off. The usual materials used are 10 to 12½ per cent. sulphuric acid or 2 per cent. sodium chlorate, used at the rate of 100 gallons per acre. These sprays also kill weeds and make lifting much easier. This work is now frequently done by contractors. A fortnight should elapse between spraying and lifting.

Lifting can be done by the potato plough—which is simply a ridging plough with a breast of steel slats which allows soil to pass through but forces out the tubers—by spinner, or by elevator digger. Harrows are run over the ground to uncover any potatoes left by the pickers.

Potatoes are best stored in small clamps; they are less liable to heat, and storage rots, etc., can be isolated more easily in small clamps than in large ones. The base of the clamp should normally not exceed 5 to 6 feet, and should not be dug out more than is essential to make it level. A dry, sheltered site is obviously desirable. Plenty of straw must be used

to cover the tubers, kept in place in the first instance by odd spadefuls of soil. When convenient a layer of earth 4 to 6 inches thick is placed on the straw, but the ridge is left uncovered for at least a month to allow "sweating" to proceed. Early in December another foot of soil is added; opinions differ about the necessity of leaving ventilation holes after this date, but this is usually done. Many potatoes are now stored in clamps made of tightly packed straw bales, thatched over. The bales should be built up edgewise to give full protection from cold. Potatoes can be stored in buildings, but adequate strawing is essential to combat the freezing draughts common in such structures.

Yield.—The average yield of potatoes is about 7 tons per acre. Good crops weigh 12 to 15 tons per acre.

SUGAR BEET

Sugar beet is most suited to deep, light loams well provided with lime. It will grow well in fen soils and also on stiff ground, but for convenience in lifting and utilisation of the tops the light lands are preferred. Wet and poorly drained soils, and soils with ironstone or other pans, are unsuited to sugar beet. A comparatively dry climate suits the plant, which has a very long and penetrating root which protects it against drought. For the production of sugar, plenty of sunshine is necessary, especially towards the autumn, and dry conditions during November greatly facilitate lifting. For these reasons the bulk of the crop is found in the eastern counties and the midlands, though a considerable acreage is grown in East Yorkshire.

Varieties.—Practically all our varieties of sugar beet have been derived from Continental sources. Prior to 1940 most of the seed used in this country came from abroad, but now we are self-supporting in sugar beet seed and even export a small quantity. Farmers are able to choose their varieties from the selection offered by the factory which issues seed to contracting growers.

It is customary to classify sugar beet varieties into three types: type "E," high root yielders; type "Z," high sugar yielders, and type "N," intermediate. The table below gives at a glance the classification of the better known varieties of sugar beet.

Type "E" *High root yielders*	*Type "N"* *Intermediates*	*Type "Z"* *High sugar yielders*
Sharpe's Klein E	Johnson's Perfection N (S.R.)	Marster's (S.R.)
Johnson's Perfection E (S.R.)	Webb's No. 2 (S.R.)	
Cannell's No. 22 (L.)	Garton's B (S.R.)	
Cannell's No. 937 (R.)		
Battle's E (L.)		
Garton's C		
Bush E (L.)		
British S.K.W. (L.)		
Goldsmith's Dobrovice (L.)		

S=Small top
R=Resistant to bolting
L=Large top

For general cultivation, strains of the "E" type are most popular; these are bred to give very high root yields combined with a reasonable sugar content. Klein E is a consistently good cropper and sugar producer. Johnson's Perfection is derived from Kuhn E. Battle's E (formerly called Battle's Dippe E) is similar to Klein E. Bush E was formerly known as Buszcznski N.P.; sometimes it is prone to bolt. British S.K.W. (formerly called Schreiber S.K.W.) is not one of the heaviest-yielding varieties and is also prone to bolt. Dobrovice is also a relatively poor yielder of both roots and sugar and tends to produce bolters; it is not recommended for early sowing.

Johnson's Perfection N is derived from the well-known Kuhn variety. Garton's B is also of the Kuhn type.

On very rich silt soils and fen land it is an advantage to have beet with small tops, because in these areas the tops are not so much in demand for feeding and are not so valuable for ploughing in. Strains such as Marster's, Webb's No. 2 and Johnson's Perfection E and N are recommended for these conditions; also for close spacing of the rows.

On the other hand, where the tops are of particular importance for feeding, strains of beet like British S.K.W. and Goldsmith's Dobrovice may be preferred.

For very early lifting it pays to use a strain with a high sugar content, such as Marster's.

Some varieties, if planted very early, may bolt or run to seed a few weeks after planting. Early bolters mean a loss to the grower, for they are not acceptable to the factory because of the trouble they may cause in the manufacturing process. They are low in sugar content, and if one gets into the sample removed for analysis it may lower the sugar percentage, and reduce the price paid for the consignment as a whole. Early bolters are best pulled out during the final hoeings. Late bolters are not so objectionable; they contain almost as high a percentage of sugar as normal beet (though, of course, they weigh less), and can be topped and sent into the factory. Early bolters are hard and woody at lifting time and are difficult to top.

Place in Rotation.—Sugar beet occupies part of the root shift, and on many farms has very considerably reduced the area previously devoted to turnips. Because of the beet tops and the dried beet pulp available to growers of beet, it is possible to cut down the acreage of roots grown solely for animal consumption and yet to maintain the same head of livestock on the holding. As previously mentioned, sugar beet is both a cash crop and a feeding crop. The grower of beet, however, has not absolute freedom of choice where he will plant the crop. In order to reduce as far as possible the spread of the beet eelworm, the factories have for some time inserted in their contracts a provision that beet shall not be grown on land that in the preceding year was planted with sugar beet, or mangolds for root production or seed production; nor may sugar

beet be grown on land on which swedes or turnips were grown the preceding year, unless the two crops before the swedes or turnips have been other than roots. For this purpose "roots" does not include potatoes. Beginning with the 1948 crop it is provided that sugar beet shall not be grown on land which for the *two* preceding years has carried a crop of sugar beet or mangolds, sugar beet seed or mangold seed.

Cultivations.—When sugar beet follows a cereal the first operation is to clean the stubble that autumn. This is done either by a shallow skim ploughing followed by harrowing, or by first breaking up the stubble with a cultivator, following with the harrows. The way the work is carried out depends very much upon the amount of couch grass or twitch which is present. If this weed grass is prevalent it often pays to shallow-plough under the roots and then work the underground stems to the surface with rigid tine harrows; the weed is then rolled together with chain harrows and burned in the field. Disc harrows should never be used for scarifying a twitchy stubble, for they cut up the runners and so disperse the weed even more widely. If the stubble is free from twitch it is economical to work it with cultivators. The idea is to loosen the hard soil and form a tilth in which annual weeds in particular will germinate. The resultant seedlings are then destroyed by further use of the cultivator. Naturally, this work must be begun as soon as possible to utilise the dry, sunny days of late August and early September.

The next operation is to apply what farmyard manure is available and to plough the cleaned stubble as deeply as possible. Sugar beet is a deeply-rooting plant and appreciates a well-worked soil and an open subsoil. If there is a pan, or if the subsoil is exceptionally hard, subsoiling may be attempted. This is conveniently carried out by a subsoiling attachment fixed to the ordinary plough, which will break up the under layers to an additional depth of 5 to 6 inches without bringing them to the surface. For their deep ploughing many growers like to use a one-way plough. This type of digging plough not only leaves a crumbling furrow slice, but eliminates the deep open furrows which are unavoidable when the ordinary plough is used, and so facilitates the preparation of a level seed bed. This deep ploughing should be completed soon after Christmas, and the land settles and weathers down on top until just before the seed is to be sown. It is far better to get well forward in this way than to rely upon cleaning and ploughing the land in spring, when there is a great rush of work and a natural tendency to hurry things.

Manuring.—It is quite impossible to grow satisfactory sugar beet on lime-deficient land. Land intended for the crop should be treated properly for lime, and at least the lime requirement as shown by analysis should be applied. It is possible to over-lime the beet ground, and this has happened in a number of cases where fields close to beet factories have had dressings of as much as 20 to 30 tons per acre of beet waste lime. One serious consequence of such over-liming is the occurrence of heart

rot in the beet; this boron-deficiency disease can be prevented by distributing 20 lb. per acre of borax before planting.

Beet is a crop which fully justifies proper and adequate manuring; the expense of growing an inferior crop is very little less than that of growing a bumper crop, and since fertilisers are able to increase yields very considerably they are extremely economical to use. When dung is used, the biggest returns are obtained from nitrogen. Phosphates, especially if applied some days before the seed is drilled, greatly stimulate root activity in the seedlings, whilst small amounts of potash are desirable to balance the added nitrogen. It is now known, also, that salt acts as a direct fertiliser on beet, and 3 to 5 cwt. per acre can be expected to increase the yield of sugar per acre by 3 to 5 cwt. A good general fertiliser for light loams which have been dunged is:

3-4 cwt. sulphate of ammonia
3-4 cwt. superphosphate
1 cwt. muriate of potash
3 cwt. salt

The salt should be applied a week or so before sowing, and the remainder of the dressing before drilling the seed. Only for special circumstances, such as a period of cold, dry weather which causes stagnation of growth, is top dressing with nitrogen economically justified. Fen soils are exceptional in that they give very little response to nitrogen used on sugar beet crops.

Seed-Bed Preparation and Sowing.—The width of the rows has a great influence upon the yield of sugar beet, a much greater influence than the distance apart in the rows of individual plants. For maximum yield of roots (which is all the farmer need concern himself with) very close rows, 14 to 16 inches apart, are necessary. But, of course, not many farmers are equipped with either implements or with operators capable of working in rows of less than 18 inches apart. Nor is the maximum crop necessarily the most profitable crop. In general, a row width as close to 18 inches as possible is generally recommended. Some growers with special row-crop equipment work down to 14 inches or even less, but special methods have to be adopted for these crops.

With rows so close together, and with the seed drilled on the flat, very careful preparation of the seed-bed is necessary. It is important to keep the top-soil moist, so that cultivations should be spread over as short a time as possible. The final touch is put to the tilth by the use of a "float" or "scrubber," which is a simple apparatus of strong planks of wood designed to leave a smooth, fine surface on the land.

Drilling is always done on the flat, and it begins usually early in April, though sowings in late March are sometimes made. Growers of large acreages of beet, space their drillings at intervals over a period of several weeks in order that there shall not be too many beet coming to the hoe at one time. The quantity of seed used is from 15 to 20 lb. per acre, the

heavier amounts being used for the earlier sowings and for the heavier soils. There is no point in economising on seed, which is one of the least expensive items in beet growing. A full plant can only be obtained from a generous seeding. The seed should not be drilled deeper than $\frac{3}{4}$ inch. Obviously great care is needed in drilling. A small harrow between the horses' feet and the drill coulters to take out hoof marks, and small weighted rollers behind the drill coulters are among the more important refinements now available.

Sugar beet seed is a cluster of woody flowers containing up to three true seeds; from each cluster may spring as many as three seedlings. It is this arrangement which makes singling so difficult, and attempts to separate the clusters into single, individual units are continually being made. The latest development is "sheared" seed, of which only 4 to 5 lb. is required per acre. The use of such seed is as yet only in its experimental stages in this country, and results so far have not corresponded with published results from America. The seed is comparatively expensive, and problems of drilling have yet to be overcome.

After Cultivations.—Singling is a very important operation, because upon its successful accomplishment depends the plant population. High yields depend upon a full population, which in theory should amount to round about 30,000 plants per acre. In practice this number is seldom achieved, for various reasons, but it is a suitable target. There is no point in trying to get the plants very close together, and an even spacing of 10 to 11 inches is very suitable. For this work an 8-inch or 9-inch hoe is used.

The ideal stage at which to single beet is the four-leaf stage (two seed leaves and two permanent leaves): the crop is reduced by about 1 ton per acre for every week's delay in singling after this stage. Early singling is vital to success. Skilled workers can do the complete singling at one operation and earn good money at piece-rates; less skilled workers should gap or "bunch" the beet, the bunches being later reduced to single plants by careful hoeing or even finger work. The strongest plant in each bunch should be left. Gapping can also be done by gapping machines, and on some fully mechanised farms cross-blocking is practised. Here the rows are sown much closer together, about 14 inches apart, and by means of special tools working across the rows the plants are cut out, leaving small clusters 14 inches apart in the original rows. These are singled out by hand within a week of cross-blocking. Very level fields, very careful preparation of the seed-bed, and meticulously careful tractor work are necessary if cross-blocking is to be successful.

Continual hoeing, which begins before thinning out, is necessary both to kill weeds and keep the soil in free condition around the beet seedlings.

Harvesting.—Sugar beet continues to grow until very late in the year, and investigations have shown that the yield of roots increases until

the middle of December, after which no further increase takes place. The percentage of sugar in the beet reaches its maximum early in November, and then declines. The net result is that the weight of sugar per acre increases rapidly until about the third week in November, after which it remains stationary. If the absolute maximum weight of sugar per acre is the aim, then the beet crop should not be lifted until late in November. In practice, of course, it is absolutely necessary to spread the work of lifting and processing the beet crop over a period of several months, October to January as a rule. In order to ensure an even inflow of beet the factories issue loading permits; these permits also ensure that all growers receive fair treatment. Consequently the time of lifting sugar beet is determined primarily by the loading permit, and not by the condition of the crop, though naturally the most mature beet will be sent off first.

Roots of sugar beet are deeply buried and it is usual to loosen them before the plants are pulled. A horse-drawn side-lifter, which is a modified plough, is run alongside the beet rows and its short curved breast slightly raises the beets. Other types of lifter have a double share, and tractor implements are available, taking several rows at a time. On small areas two-pronged spuds are still used.

It is not essential that the "lifted" beet should wilt before they are pulled, though generally a certain amount of wilting does occur because the lifter works one or more days in advance of the pullers. If sheep are to be folded immediately on the tops this extra wilting may be an advantage, since it reduces the chances of scouring, caused by the oxalic acid in the leaves.

A convenient method of arranging the lifting of sugar beet is to divide the field into sections of eight rows each. Row one forms a double row with row two; row three receives beet from row four; row five is thrown on to row six, and row seven forms a double row with row eight, the root pointing towards the roots of the other rows. There is consequently a clear space 4 to 5 feet wide in the centre of each section, in which the topped beet can be heaped. If the tops are to be carted off it is an economical plan to heap these up alongside and alternating with the heaps of topped beet; in this way they are not trampled on during the loading operations as they may be if left scattered about the field.

Topping must be done with care. The crown of the beet must be struck off squarely with a beet knife "immediately below where the lowest leaves or buds on the crown only have grown." If too much of the crown is cut off there is a loss of crop, while if too little is removed there may be technical difficulties at the factory. The factory has the right to retop any insufficiently topped beet and recover from the grower.

The topping, lifting, and loading of sugar beet are becoming increasingly mechanised. Some machines perform all the operations necessary before the roots can be sent away; others do the lifting and loading after the

crop has been topped by hand. Mechanical devices for loading hand-lifted beet into lorries are also becoming more common.

Beet which cannot be accepted by the factory until December and January may have to be clamped so as to protect it from frost. Large clamps of from 40 to 50 tons are better than small ones, and the base should be about 8 feet wide and the height 6 to 7 feet. A covering of hedge trimmings or straw is necessary only in the very hardest weather; many such clamps are left unprotected without any serious loss from frosting, though in the severe winter of 1946-47 loss through frosting was considerable in some districts where clamps were unprotected. A site protected from dry winds is desirable to reduce shrinkage to a minimum.

By-products.—The chief by-products of the crop are beet tops and beet pulp. The weight of the tops is about equal to the weight of the roots; they contain sugar, and are a valuable stock food, for in practice a ton of beet tops is about equal in feeding value to a ton of swedes or mangolds. As fed, they contain 15 to 17 per cent. dry matter rich in protein and sugar, with a proportion of oxalic acid amounting to 4·5 per cent. of the ash. This oxalic acid is laxative, and fresh beet tops are liable to cause scour in animals and taints in milk. These disadvantages can be minimised by allowing the tops to wilt before using them, and by feeding small amounts of chalk (½ lb. chalk to each 2 cwt. of tops) with the beet tops, especially to young animals and pregnant or milking older stock.

Sheep are often folded direct on to the tops as they lie in the field—1 acre of beet tops will feed 100 sheep for a week unless there is a great wastage from excess trampling. Rather less than 1 cwt. per day of tops can be consumed by a 10 cwt. bullock. Milking cows should not receive more than 40 lb. per day, fed on pasture because of the possibility of tainting the milk if fed in the cow-house.

If it is not possible to feed all the tops before they decay, a proportion may be preserved for winter and early spring feeding by making them into silage. This is best done in pits. No molasses are required as there is plenty of sugar in the crowns and leaves.

Beet tops are an excellent manure, containing 0·34 per cent. nitrogen, 0·11 per cent. phosphoric acid and 0·58 per cent. potash. The Norfolk experiments show that on light land the manurial effect of ploughing in beet tops can be traced over three crops. There is very little difference in the manurial effect whether the tops are ploughed in or fed off by sheep, but, of course, one must consider the amount of meat produced by the sheep while on the tops—this may amount to about 2 lb. per head per week live weight increase.

Dried pulp, which is the dried residue after the beets have been sliced up and most of the sugar extracted, has roughly the same feeding value as oats and makes a valuable addition to the concentrate ration. Wet pulp is sometimes available.

MANGOLDS

The mangold requires a warm climate and only a moderate rainfall. Its main root is very long and penetrates deeply into the subsoil, so that it is much less affected by drought than turnips and swedes; moreover, it does not suffer from the severe attacks of mildew which make turnip growing a risky procedure in many parts of the south and east, especially in a dry season.

Deep, strong loams suit the crop, but good yields can be obtained from light soils if they are dunged and well supplied with fertilisers. Mangolds respond very well to generous treatment. Soils which are shallow, or which have a "pan" of any sort just below the surface, are not suited to the crop because of the lengthy main root.

Varieties.—Mangolds are classified first according to their shape, and second, according to their colour. Four types of root are usually recognised—Long, Intermediate, Tankard and Globe. Long types, which bury themselves deeply, are not very common, for they have obvious disadvantages, such as difficulty in lifting and unsuitability to the shallower soils. Intermediate, or Gatepost, mangolds are more or less oval in outline, with sloping shoulders, whereas typical Tankards are squarer, with well-defined shoulders. Globe mangolds are more or less spherical. There is no hard and fast distinction between intermediates and tankards; it is very difficult to maintain type in these two classes of root, no matter how severely the seed specialist may select and rogue his stocks, because cross-fertilisation is always taking place. It is frequently a matter of opinion whether a crop is of the tankard or intermediate type.

The skin colour of mangolds is usually yellow, orange-yellow, or red. The flesh inside can be white, yellow, or red. There seems to be no relation between the shape and colour of the root and the yield.

There is a considerable variation in the chemical composition of mangolds. In the N.I.A.B. trials already mentioned the percentage of dry matter varied from 9·2 to 13·6 per cent. The richest in dry matter is Kirsche's Ideal, a white-fleshed tankard with a rather large top. It is, of course, not much use having a high percentage of dry matter in the individual root unless the variety crops heavily as well. Golden Tankards, for example, have about 11·7 per cent. dry matter, which is comparatively high, but they do not yield well; the total weight of dry matter per acre they produce is less than that, for instance, of yellow globes having only 9-10 per cent. of dry matter but a heavier yielding capacity. Most of the well-known seed houses market their own selections of yellow, orange and red intermediates, and yellow and orange globes. Generally speaking, the keeping quality of these varieties is satisfactory.

Place in Rotation.—Since a large acreage of mangolds is seldom grown on the average farm, and because the crop can be grown year after year on the same land without apparent ill effects, it is a common practice to reserve the same convenient field, or portion of a field, for

mangolds every season. It is very handy to have the mangold break close to the farmstead, so that singling can be done at odd times; likewise, the labour of carting home the crop is much reduced. Also, since it is usual to muck the land for mangolds, much haulage is saved by having the crop close to the buildings, while simultaneously the fertility and workability of the soil are built up by the muck, the land is kept clean, and heavy crops are ensured.

If a special place is not reserved for the crop, mangolds occupy part of the usual root area.

Cultivation.—Mangolds give of their best when the soil has been deeply cultivated, has been consolidated, but is fine on the surface. They need the same sort of conditions as sugar beet. On some farms it is the practice to apply the dung in the ridges as for potatoes, and this dunging and ridging may be carried out either before Christmas or in spring.

Mangolds can be planted on the ridge or on the flat; probably on the ridge is the more popular method. It enables the farmer who is well ahead with his work to kill large numbers of germinating weeds before sowing his mangolds, by running the harrows over the ridges. More important still, the ridge enables him to start side-hoeing very much earlier than would be possible with a crop sown on the flat. The ridges are usually from 24 to 27 inches apart.

Manuring.—For mangolds it pays to be as generous as possible with dung or farmyard manure, and to supplement this dung with nitrogenous fertilisers. An application of as much as 20 tons per acre of dung can be made, and this can be spread and ploughed in, or put into the ridges. The fertiliser dressing decided upon should be worked into the ground before sowing the seed; the practice of applying part of the fertilisers before seeding and part just after singling has been proved unsound.

Nitrate of soda and nitro-chalk give slightly better responses with mangolds than sulphate of ammonia; up to 3 cwt. per acre of a nitrogenous manure can be relied upon to give increasing yields, but it is desirable to balance this with some phosphate and certainly with some potash. As with sugar beet, salt gives good results by supplying the sodium which the crop demands. The complete manurial dressing may therefore be as follows:

Farmyard manure	10-20 tons
Nitrate of soda	1-3 cwt.
Superphosphate	3 cwt.
Muriate of potash	1 cwt.
Salt	3 cwt.

The salt should be applied separately some time before sowing.

Sowing.—Mangolds are the first root crop to be sown, and are drilled from the beginning of April to the end of May, according to the

district. Very early sowing is undesirable as there is then a tendency for the plants to bolt, while the seedlings may suffer a check if frosts and generally cold weather occur while the plants are very small. While early sowing is recommended, some surprisingly good crops have been obtained from seed sown at what would be considered ridiculously late dates.

The average rate of seeding is 8 lb. per acre, the limits being 6 to 10 lb. Depth of drilling should not exceed 1 inch, and it is for this reason that a fine tilth overlying a firm bottom is so desirable for mangolds.

After Cultivations.—Annual weeds seriously hinder the healthy growth of mangold seedlings, and interrow cultivations should be begun as soon as the first crop of weed seedlings is visible. Some farmers begin horse- or tractor-hoeing the ridges before the mangolds are showing, while others prefer to let the crop "chit" before starting in. On some farms where drilling on the flat is practised, a small amount of turnip seed is mixed with the mangold seed; the turnips appear very quickly and give the men a line several days earlier than would otherwise be the case.

Singling begins with the first signs of the permanent leaves in between the seed leaves or cotyledons; this is usually five or six weeks from drilling, according to soil and weather conditions. The plants may be gapped or bunched, and gone over and finally thinned a second time; or they may be completely singled at one operation. The interval between plants is about 12 inches.

Interrow workings continue until the leaves meet in the rows. Gaps can be filled up by transplanting or, if the intervals are very long, by drilling in turnip seed or even kale.

Harvesting.—Mangolds are the first root crop to be harvested as they are very susceptible to frost and do not keep well if frosted. The roots are pulled and the tops either twisted off or cut off with a suitable knife. No "tailing" of the root is permissible. The roots are piled up in heaps and at once covered with leaves in case a frost occurs before they can be taken to the clamp. At one time it was considered essential to cover the mangold clamp with many inches of soil, but labour costs are now so great that the tedious and heavy work of earthing the clamp is now omitted where possible. A generous covering of straw, supplemented in hard weather after Christmas with hedge trimmings, bracken or gorse is sufficient to keep out frost. If the clamp is earthed up plenty, of ventilating holes must be left. Many crops are now stored between walls made of straw bales, with a roof of loose straw. Some farmers, too, have begun to lift and store their mangolds without removing the tops.

As lifted, mangolds are unripe, and should not be fed until after Christmas. Until they mature in the clamp they are liable to cause scour and digestive troubles. They improve with keeping and are possibly most palatable in late spring when the young leaves begin to develop on the crown of the bulb.

TURNIPS AND SWEDES

Turnips are essentially a crop for cool, moist climates, just as mangolds are pre-eminently a crop for warm, dry districts. It is in Scotland, in Northern Ireland and in the northern counties of England that turnips are grown to perfection. In southern districts, particularly in the dry belts, turnips do not give the excellent yields and high-class feeding value which northern farmers expect from their crops as a matter of course. Turnips and swedes have been, and are still widely grown in the arable districts of Norfolk and adjacent counties, and in Wiltshire and other Down counties, but they do not give such high weights of dry matter per acre as they do in moister districts. In very dry areas there is a constant fight against the flea beetle (Fly), while mildew also is a source of trouble.

Light, easy working land suits turnips, because it is essential to provide the seedling with a fine, moist seed-bed. On heavy land it is very difficult indeed to obtain such a fine tilth, and in knobbly conditions the turnip seedling makes slow growth and is liable to suffer badly from the competition of weeds. On strong land it is better to substitute mangolds for turnips. On stiff land, also, it is often impossible to feed the crop in the field, and it was the sheep flock folded on the roots which gave the turnip its reputation.

Varieties.—The turnip differs from the swede in several particulars. Turnips have grass-green, rough leaves arising direct from the top of the "bulb"; swedes have ashy-green, smooth leaves situated on a short stem or "neck" growing from the top of the swollen portion. Turnips have a higher proportion of water than swedes; in turnips the dry matter amounts to about 8 to 14 per cent., in swedes to 10 to 15 per cent. Turnips grow more rapidly than swedes, but are less resistant to frost. Turnips give a higher gross yield of roots per acre than swedes, but the total amount of dry matter produced per acre is probably about the same. Weight for weight, swedes are more nutritious than turnips. Danish experiments have shown that the actual *dry* matter of turnips and swedes has a feeding value similar to that of barley; a good crop of turnips, say 20 tons per acre, having 10 per cent. dry matter, would therefore produce rather more feeding material than a good crop of barley—2 tons per acre.

Turnips are of two main types, according to the colour of the internal flesh: white turnips and yellow turnips. White turnips have a very low percentage of dry matter, about 8 to 9 per cent., but they crop heavily and grow very quickly. Because of their very watery nature they are low in feeding value, do not keep for long, and are easily damaged by frost. Because of their rapid growth they can be sown very late in the season, and are useful for filling in gaps in other root crops, for planting headlands, and for catch cropping. Although the flesh is white, the outside skin can be green, purple or mottled. The mottled type are sometimes called "greystones."

Yellow-fleshed turnips are less watery than white turnips, the percentage

of dry matter being about 10 per cent. Some of them are not much more resistant to frost than white turnips—they are called soft yellow turnips. Hardy yellow turnips approach the true swedes in chemical composition, feeding value, and keeping quality. There are green-top and purple-top varieties. The Wallace is a green-top variety resistant to club root disease. The Bruce is a purple-top variety similarly resistant.

Swedes vary quite a lot in the colour of the outside skin, though the internal flesh is nearly always yellow. Four groups are recognised: (1) Green skin, (2) Dark purple skin, (3) Light purple skin, (4) Bronze skin.

(1) Green skin strains are of two main types, both having small tops and small necks, e.g. Wilhelmsburger and Wintergreen. Both strains are frost resistant to a high degree. Wilhelmsburger is also resistant to club root disease.

(2) Dark purple skin strains are chiefly of the globe type, though tankard-shaped varieties such as The Elephant and Monarch exist. They give moderate yields with high dry matter percentage, and are resistant to frost. Examples are Bangholm, Champion, Purdy's Purple Top, Acme, Tipperary.

(3) Light purple skin strains yield rather more heavily, with a slightly lower dry matter percentage. They are less resistant to frost. Examples are Angus, Eclipse, Majestic, Magnificent.

(4) Bronze skin strains are of a very mixed nature; some are very resistant, others less resistant to frost. Varieties with white flesh are included. Examples are Lord Derby, Lion, Jubilee, Mancunian, Pioneer.

Place in Rotation.—Turnips are traditionally a cleaning and restorative crop. They are usually well-manured and they are consumed on the farm, so that in these two ways they tend to store fertility in the land. They demand thorough cultivation of the soil and suppression of weeds if they are to succeed, and the benefits which accrue from their intensive management are shared out over the other crops in the rotation. When properly managed, the root break certainly does benefit the whole cropping system. But if, as is sometimes the case, the root crop is not properly manured and the weeds are allowed to grow, turnips can become anything but a cleaning and restorative crop. There is no particular virtue in a turnip as a "cleaning" agent; the crop merely offers a chance of cleaning the land and building up fertility, and it is the management rather than the crop itself which is important.

Cultivation.—A very fine, moist tilth is desired for turnips, and cultivations must be managed to this end. In dry regions autumn cleaning of the stubble, principally to eliminate any couch grass or twitch, is followed by as plentiful a dunging or mucking as possible. This manure is ploughed in and well covered. Whether or not a second ploughing is given will depend upon circumstances; such a second ploughing must not bring the manure to the surface, nor must it be done so late that weathering is impossible on the stronger soils. In spring the land is repeatedly worked, either with tined cultivators and harrows or with disc

harrows, with the double object of obtaining a fine tilth and destroying weeds. The overriding principle is to retain the surface moisture, and clods must not be permitted to dry out. By harrowing and rolling, a fine, moist tilth resting on a firm bottom is obtained for sowing turnips on the flat. In dry climates this reduces the risk of failure from drought.

In wetter regions turnips are usually sown on the ridge, because this simplifies singling and makes it possible to start the horse hoes sooner. In spring the ploughed land is worked down from the surface by tined implements and is then ridged up at about 2 feet intervals. Well-rotted dung is put down the ridges, which are split back to cover the manure as soon as the fertilisers have been broadcast.

Manuring.—The first step in growing a good crop of turnips is to make certain that the land is properly supplied with lime. Turnips will grow on lime-deficient land, but do not crop so well as on limed soils; shortage of lime predisposes the crop to attack by the club root fungus, which is one of the turnip's most important foes.

The value of farmyard manure has already been stressed, and a dressing of from 12 to 15 tons per acre is extremely beneficial. The next most important manure for turnips is phosphoric acid, which is probably best supplied as superphosphate, except on acid soils where basic slag may be substituted. Even where dung is used, superphosphate up to 3 to 4 cwt. per acre will give an economic return; similarly, nitrogen in the form of sulphate of ammonia—1 cwt. per acre—can be used to supplement the nitrogen in the dung. Potash is not essential where farmyard manure has been given. Where turnips have to be grown entirely without dung as they frequently are in the big sheep-feeding counties, a complete manure should be used, such as the following—superphosphate 3 to 4 cwt., sulphate of ammonia 1 to 1½ cwt., muriate of potash 1 cwt. This quantity of nitrogen is rather more than is commonly used, but Scottish experiments have demonstrated the value of additional nitrogen in increasing the yield of turnips.

Seeding.—Where turnips are planted in the ridge it is usual to space the rows about 27 inches apart, but if sown on the flat the rows can be appreciably closer, from 20 to 24 inches apart. Nowadays the planting distance depends very much upon the mechanical equipment available for row-cropping work.

Swedes, which grow more slowly than turnips, are planted first, beginning about the second week in April, according to district. Yellow turnips are sown next, and white turnips can be drilled late in June. A catch crop of white turnips, consisting very largely of the tops, can be obtained from a broadcast seeding on a disced stubble in August and September. The date of sowing depends very much upon the rainfall that may be expected during the summer.

Very small quantities of seed are required per acre. Swedes, which have a larger seed than common turnips, are usually drilled at about

4 lb. per acre. Turnips are drilled at from $1\frac{1}{2}$ to 3 lb. per acre, depending upon the tilth and upon the prevalence of the turnip flea beetle, the argument being that a full stand gives a better chance of a successful take if the "fly" is troublesome.

To minimise damage by flea beetle all sorts of preparations have been used as a seed dressing. Paraffin oil and turpentine are two of the commonest, the turnip seed being moistened with the least possible quantity before drilling. How far these materials act as deterrents is an arguable matter.

After Cultivations.—The destruction of weeds must begin as soon as possible, since annual weeds grow very rapidly in the heat of early summer in the fine tilth prepared for the crop. One of the chief advantages of drilling on the ridge is that hoeing can begin at any time without danger of working up the turnip seedlings. Horse labour is commonly used, but row-crop tractors are becoming more widely used as farm mechanisation develops. Disc hoes have the advantage of protecting the turnip seedlings from being smothered by the dislodged soil. Singling is begun as soon as the rough leaves appear between the smooth seed leaves or cotyledons. This is usually done by hand hoes, and all the soil between the plants to be left should be pushed aside. The plants may be completely singled in one operation, or they may be gapped or bunched and be gone over again to avoid doubles. The distance between plants is from 8 to 10 inches.

If the flea beetle becomes numerous, steps must be taken to avoid loss of plant. The dragging over the plants of sacks soaked in paraffin is a very old method of control, but it is fast becoming superseded by dusting the plants with one of the new proprietary "dusts." These may be applied by a horse- or tractor-drawn mechanical duster, by a hand-blower, through a fertiliser drill, or they may be distributed by being shaken from a loosely-woven bag held by a man walking down the rows.

Interrow cultivations, which stir only the top layers of soil, are continued as weather conditions permit, until it is no longer possible to get between the rows of plants.

Harvesting.—Turnips intended for folded sheep are either left in the ground and eaten off direct, or are stored in small clamps in the field. Turnips for cattle feeding are lifted and stored in clamps. White turnips often are not clamped as they store badly, and so they are fed early. Before being clamped the roots of yellow turnips and swedes are "topped and tailed." It is a common practice in root-growing districts to leave a proportion of swedes in the ground until required. To protect them from frost a layer of soil is ploughed up over the bulbs on both sides, but in some areas where severe weather is uncommon swedes may be left entirely unprotected. Turnips and swedes, properly harvested and stored, will keep in good condition until March, but are outlasted in this respect by mangolds.

Yield.—A good crop of white and yellow turnips is 20 to 25 tons per acre. Swedes do not crop as heavily, and 15 tons would be considered satisfactory in many districts.

KALE

Kale (or Kail) of various kinds has to a considerable degree replaced mangolds and turnips as a stock feed, mainly because it is easier and less laborious to grow and because, as a general rule, it does not have to be protected from frost by lifting and clamping before it is used. On the other hand, it is a messy and uncomfortable plant to handle in wet and frosty weather if it has to be cut and carted to stock instead of being grazed. A well-grown crop of kale acts as an excellent smother crop and leaves the land clean of weeds.

Kale will grow on any soil which will support turnips or mangolds and, like most of the Brassica tribe, it responds well to generous treatment.

Varieties.—The following kinds of kale are grown in this country.

Thousand-head or Open-head Kale.—This kale has been cultivated for many years. It has a shortish, solid stem about 2 feet long which carries a number of branches bearing large, more or less uncurled leaves. It is hardier than marrow-stem kale, and can usually be relied upon to provide green fodder in January, February and possibly March, before running to flower.

Marrow-stem Kale has become popular during the last forty years. It has, when grown with plenty of space, a thick stem about 3 feet high filled with palatable pith or marrow, and a heavy crop of leaves. There are two kinds, green-stemmed and purple-stemmed; the green-stemmed is the more popular as it yields more heavily, though the purple-stemmed variety is said to be hardier. Marrow-stem kale has very largely ousted the thousand-head variety, though it is not so hardy; it is said to be a cross between Kohl rabi and thousand-head kale.

Rape Kale has a short, stumpy stem bearing a number of very curly leaves, and its production per acre is very much less than that of the two types just described. It is, however, very hardy, and after being grazed down can, in cases of necessity, be allowed to remain and throw up another set of leaves.

Hungry Gap Kale is possibly a cross between rape kale and rape; it was introduced about fifteen years ago. It has a comparatively slender, succulent stem, bearing a number of leafy side-shoots. It is hardy and produces useful fodder late in spring, but its yield does not approach that of the older established kales.

Cultivation and Management.—Kale usually takes part of the root break in a rotation or is grown as a catch crop. The preparation of the ground is similar to that already described for turnips. Kale is either

drilled or broadcast, although it is possible to transplant from a seed-bed either to fill up gaps or to plant up an area on which the "fly" has carried off successive sowings during the summer. Drilling is done either on the flat or in ridges. If there is no intention of thinning the kale, drilling on the flat is the cheaper and easier method. The distance between the rows varies from 24 to 27 inches. Thinning or singling is now very commonly omitted, chiefly because of labour difficulties, but also because many growers think that a crop consisting of numerous, medium-sized stems, gives more nutrients per acre than a crop of more widely-spaced plants with gigantic and rather coarse stems. There is some evidence that the thinning of thousand-head kale is more desirable than thinning marrow-stem kale.

Drilling begins as soon as the land is in proper fettle, and it is essential to have a fine, firm tilth to get the seedlings away to a good start. The end of March is a common time to begin drilling, and though it may continue through April, May and June, the heaviest crops are obtained from the earlier plantings. Sowings after the end of June do not lead to very large plants of marrow-stem kale, and in many districts seed is then broadcast fairly liberally (5 to 6 lb. per acre) to provide a dense crop of slender, but leafy plants.

For drilling, 4 lb. of seed per acre are needed. If transplanting is contemplated, $1\frac{1}{2}$ lb. of seed will provide enough plants for 1 acre.

As with turnips, the chief enemy of the kale is the flea beetle or fly. The new insecticidal dusts, applied either in the drill or over the seedlings, make it possible to protect the crop more successfully than in the past.

Manuring.—Kales are gross feeders and respond well to large applications of nitrogenous fertilisers. A dressing of dung forms an excellent basis for manuring kale.

Utilisation.—Marrow-stem kale is used first, as it is not really hardy in a severe winter, and it is at its best only for a short period before Christmas. The practice of making kale silage is increasing with the twin objects of preserving the crop while it is at its best and eliminating the mess and discomfort of daily cutting in wet weather when the land is sodden.

RAPE

There are two types of rape—one with leaves resembling a swede; another, much less common, having rough, turnip-like leaves. In the early stages rape is indistinguishable from a swede, and when mature it consists of a shortish, thick stem which, however, is never bulbous, and abundant leaves. There are two commercial varieties—Giant, which is said to be the better on light land, and Essex Dwarf, which is recommended for more fertile soils.

It will succeed on a great range of soils, but, because it is almost always grazed off, rape is mainly sown on light to medium land.

Rape is used as a catch crop, as a pioneer crop on reclaimed land, and as a nurse crop for long or short leys, especially in the hillier and wetter districts. It is interesting to note, however, that in Sir R. George Stapledon's opinion, Italian ryegrass is almost always a more profitable nurse for leys than rape. Rape is one of the most rapidly developing of forage crops, and may be expected to yield abundant forage in three or four months from date of sowing; in feeding value it is superior to swedes. Mixtures of rape and Italian ryegrass are sown after early potatoes for making into silage.

The cultivations for rape as a catch crop are usually of the simplest, especially after early potatoes. Broadcasting is almost always practised; the rate of seeding is 8 to 12 lb. per acre when grown alone, but for a nurse crop of grass and clover 2 to 3 lb. is sufficient. It is essential to graze rape quite early when used as a nurse, otherwise it may smother the ley.

As with all luxuriant forage plants, dressings of nitrogenous fertilisers give good results. Phosphates, and sometimes potash, are necessary on reclaimed land to obtain a good crop of rape, and the chief object here is to graze with sheep, or cattle, to add "stock nitrogen" and encourage bacterial activity in the soil.

CABBAGES

Cabbages as a crop are more popular in some districts than others. They are bulky and contain a high proportion (85-90 per cent.) of water, but if well grown they produce quite as many nutrients per acre as kale. They have several advantages over kale; for example, they are hardier, take less time and are more comfortable to cut and load, and there is less waste.

If fed properly cabbages will grow in a great variety of soils, though they do best on the stiffer types. They do not succeed on light land in dry climates unless heavily dunged or grown under sewage farming conditions.

Varieties.—Cabbages can be classified in a variety of ways, but it is convenient to consider them first as either Drumheads, Oxhearts or Savoys. Drumheads are the largest cabbages, with spherical heads rather flattened on top; Oxheart cabbages are cone-shaped, while Savoys resemble Oxhearts in shape, but have crinkled instead of flat leaves. The colour of the leaves is green or purple, and with regard to time of maturity there is considerable gradation between early and late varieties. Purple pickling cabbage, though not sown specially for stock, makes an excellent stock food if market conditions render it unsaleable.

Manuring.—Cabbages are "gross" feeders and respond well to generous doses of farmyard manure and nitrogen. Nitrate of soda appears to be specially acceptable to cabbages, and one to three top dressings (each of 1 cwt. per acre) per growing season are profitable, despite the labour involved in hand-placing the fertiliser at the base of each

individual plant. If dung is not available a basal manuring of 3 to 5 cwt. superphosphate and 1 cwt. muriate of potash per acre is advisable, combined with, say, half the nitrogenous dressing.

Planting.—Cabbages are usually planted as part of the root break, and the preparation of the land for this purpose has already been described in the sections dealing with turnips and mangolds.

There are many ways of growing cow cabbage, but the most popular is possibly that of transplanting seedlings either from a seed-bed on the farm or from a nurseryman specialising in the work.

In order to obtain a succession of plants for planting out it is necessary to sow seeds at different times in prepared seed-beds. The first sowing is made in August; seedlings are either left *in situ* until March or April, or planted out in October; they come into use from the following July to September. Another sowing in the seed-bed is made in February or March, to be transplanted during spring ready for use from October onwards. Seed can then be drilled direct with an ordinary root drill at 3 to 4 lb. per acre in rows 24 to 30 inches apart in June or July. These rows are gapped with the hoe to leave the plants 18 to 24 inches apart, according to variety and time of sowing; the plants come into use the following spring.

In planting from a seed-bed various methods are adopted. For large areas mechanical planters can be used, but this method does not permit cross cultivations, so that many growers still stick to hand-planting on marked out ground. The marks are made by a horse- or tractor-drawn marker (with legs up to 3 feet apart for drumhead cabbages) working first in one direction, then at right angles. Plants are dibbed in where the lines cross each other, giving the plants 3 feet in all directions.

Cabbage plants may also be ploughed in; they are placed by hand along the furrow and covered as the plough comes along the next time. Sometimes cabbages are planted on ridges.

For drumhead cabbages set at the maximum width of 3 feet, 5,000 plants per acre are needed. At an all-round distance of 2 feet 6 inches about 7,000 plants are needed, and so on. Seed in a nursery bed can be broadcast or drilled; if seed is drilled it is possible to keep down the weeds between the rows by hand hoes, whereas a broadcast bed soon becomes very dirty. About 15 to 20 lb. of seed are needed per acre of seed-bed, which should supply enough plants to plant out 20 acres.

Yield.—Well grown oxhearts weigh 28 to 30 lb. each, giving a yield per acre from a yard-apart planting of about 60 tons; a cabbage of this weight is sufficient for a cow at a meal. A yield per acre of less than 25 to 30 tons would be looked upon as unsatisfactory.

LINSEED AND FLAX

These two very different products—linseed and flax—are both derived from the same species of plant, *Linum usitatissimum*. Linseed is the seed,

and flax is the fibre of the stem which forms the raw material of the linen industry. By selection and by breeding, different strains of the plant have been evolved, some of them providing a plentiful amount of oil-rich seed, others a relatively high proportion of long, tough, bast fibres in the stem and a relatively poor crop of seed.

The Cultivation of Linseed.—It is a crop which will do well on a variety of soils if properly managed. On chalky land, or on thin, sandy soils, lack of water is frequently the limiting factor. The seedling, and also the maturer plant when just coming into flower, are very susceptible to drought, so that on this type of soil yields are almost certain to be low. Clay soils will support good crops if the seed-bed is really fine and provided the surface does not "run together." Medium soils which are not too shallow grow the best crops.

Varieties.—Until 1940 almost the only linseed sown in this country was La Plata, or Plate linseed from the Argentine, and "English blue-flowering" linseed. Plate linseed is a mixture of types from the La Plata district of Argentina, and English blue-flowering linseed, existing in several ill-defined strains, is more closely related to the types grown in India and California.

Since 1940, improved types of linseed have been imported from Canada and America, the most important being Redwing, Royal and Bison.

Manuring.—Linseed should not be planted on very rich land or on ground which has been dunged for the previous crop, because of the danger of the plant running too much to stem and lodging. On old arable land a top dressing of 1 to 1½ cwt. per acre of sulphate of ammonia may be advantageous. No response whatever to phosphates has been observed in experimental work, so the use of slag or superphosphate is unnecessary and wasteful. Only if the land on analysis shows a high deficiency of potash should potash be needed for the crop.

Place in Rotation.—Linseed makes a useful first crop in recently ploughed old turf suspected of containing a high population of wireworms, for the pests more or less ignore linseed. It is a useful crop, too, on land close to woods and rabbit warrens, for it is less attractive to rabbits than any other farm plant. Linseed makes a useful nurse crop for ley seeds provided strong-growing plants like Italian ryegrass and broad red clover do not form more than a very small proportion of the seeds mixture, in which case the linseed may be smothered. The land must be clean, for linseed seedlings cannot compete with annual or perennial weeds. Wheat usually follows linseed quite successfully.

Cultivations and Planting.—The seed of linseed is not large, and the growing period of the plant (100 to 120 days) is short; it is consequently necessary to have a fine tilth resting on a firm bottom to give the seed a rapid and even start. Cultivations must be directed towards this aim as described for other crops, particularly barley.

Planting must be done early for best results. Linseed has acquired an undeserved bad reputation among farmers largely because it has so often been planted late, with the result that it has yielded badly and ripened late. Linseed will give a crop if planted in May, but every effort should be made to drill it as early as possible in April. This gives the seedlings a chance of escaping spring drought.

The rate of seeding is 60 to 80 lb. of seed per acre drilled with the ordinary corn drill. There is evidence to show that cross drilling 40 lb. of seed each way gives higher yields than drilling one way only. A depth of about 1 inch should be aimed at. Harrowing after drilling, followed by a rolling, finishes the planting operation. On strong soils liable to cake, it may be policy not to roll after drilling.

Harvesting.—The crop is ready to harvest in from 100 to 120 days after planting, according to date of sowing, etc. Signs of ripeness are the fall of the leaf, the browning of the straw, and the browning of the seeds in the "boll" or seed capsule. Not all the bolls will ripen together, so harvesting must begin when some of the seeds are not fully matured.

When cut with a binder the sheaves should be made as small as possible, and stooked in the usual way. They can be carried in a few days and stacked. When threshing, linseed riddles are necessary and the sheaves must be fed slowly into the machine, though a daily output of 40 cwt. of seed should be possible.

Linseed can be successfully combined if allowed to become dead ripe, but artificial drying of the seed is essential to prevent moulds developing.

Yield.—The average yield of the older varieties was about 10 cwt. per acre; a good crop would yield twice this amount. The yield of straw is 20 to 30 cwt. per acre, and this is useless except for trampling into muck or covering root clamps. It cannot be used as fodder. The chaff, however, can be fed to stock.

Cultivation of Flax.—Flax is grown solely on contract with the flax factories, and is consequently more or less confined to areas within a convenient distance of a factory. Growers must conform to certain conditions, but in return are supplied with technical advice from the staff of the processing factory.

Only the variety of flax supplied by the factory may be used. Modern varieties are much improved and yield a greater weight of first-quality fibre than the types available say twenty-five years ago.

The general principles already discussed for linseed regarding place in rotation, manuring, planting, etc. apply to flax production. Drilling is usually practised, special flax drills with spouts only 4 inches apart being increasingly used. Drilling facilitates harvesting. Clean land is essential because a weedy crop is a great nuisance in the factory, so much so that penalties may be enforced by the factory for crops containing more than a certain proportion of weeds.

Harvesting.—Flax cannot be cut, it must be pulled either by hand or machine. It is ready to pull when the leaves have dropped off the lower half of the stem, which itself has turned yellow in colour. The seeds at this time are just beginning to turn brown. The stems are tied into small sheaves, or "beets," and stooked as for corn. If not required at once by the factory the beets are stacked and thatched in the usual way.

MAIZE

Maize has long been cultivated on a small scale in south and south-east England as a fodder and silage crop. Its spread is largely influenced by climatic conditions, for it is very susceptible to frost at both ends of its life. It has, however, been grown as far north as Yorkshire, and at considerable elevations in parts of the Midlands. The production of hardier, quicker-growing varieties would considerably extend its range. Apart from its usefulness for silage, maize is a great standby in dry districts where the pastures drought off and become unproductive during July and August. Maize, cut and fed on grass during these times of scarcity, is invaluable to the dairy farmer.

The richer the soil the better the crop of maize. Heavy clays are not very suitable as there may be difficulty in getting a tilth, but loams, fen soils and well-manured light lands are capable of supporting big crops of maize.

Varieties.—For a very long time varieties like White Horse Tooth and Giant Caragua have been recommended for British conditions. These varieties grow rather slowly and although the weight per acre of green fodder which they produce in September may be immense, their feeding value is not high; they are low in dry matter, and they do not produce cobs. Jaune Gros du Domaine is an earlier maturing variety than White Horse Tooth. Recently a great deal of work has been done, particularly in the United States, on quick maturing varieties of maize for fodder purposes. The conclusion is that, to give maximum weight of nutrients per acre, a variety of maize must be used which is capable of cob development. Wisconsin 420 appears to be as promising as any variety so far tried out in this country.

Place in Rotation.—Maize is seldom grown on a large scale, and proximity to pastures or to the silo is one of the most important considerations. For this reason, some farmers grow their small patch of maize year after year on the same site. Maize is often looked upon as part of the root crop, and following a corn crop it can help in cleaning the land of squitch and annual weeds, though it cannot compete with thistles.

Manuring.—The heavier the manuring the bigger the crop of maize. A good dressing of dung is an excellent beginning, plus a generous application in the seed-bed of mixed fertilisers similar to that used for potatoes, or say 3 to 5 cwt. superphosphate, 2 to 3 cwt. sulphate of ammonia,

1 to 2 cwt. muriate of potash. A top dressing of sulphate of ammonia is given if the plants seem to need it later on.

Seeding.—Planting must be delayed until all risk of frost is past; this will usually be the second or third week in May in the earlier districts, and the beginning of June in later areas.

Seed must be deeply set, otherwise rooks will do great damage; $2\frac{1}{2}$ to 3 inches deep is probably the optimum depth.

Maize is planted in rows so that interrow cultivations can be practised. The row width varies from 20 to 24 inches, according to circumstances, and seed can conveniently be sown with a bean drill or ordinary cup feed drill. Very small areas can be drilled with a Planet or similar hand drill.

The amount of seed required per acre depends partly on the width of row, partly on the variety used, and partly on the germination of the seed (which may be low). From $\frac{1}{2}$ to $\frac{3}{4}$ cwt. per acre are common limits.

Horse-hoeing between the rows, plus a certain amount of hand work, is needed to keep the crop clean in the early stages. As the maize lengthens it acts as a smother crop. It is not usual to thin out the plants in the row.

Utilisation.—For direct feeding, maize is used from August onwards, according to the state of the pastures. It can be cut by hand or by a mower and carted out as required. Maize grows rapidly during August and early September, but becomes fibrous towards October, even if it escapes being frosted.

Surplus maize can be converted into excellent winter feed by ensiling it while still in good condition.

MIXED CORN CROPS

Although it has been customary for very many years to grow the individual cereals, beans and peas separately, evidence is slowly accumulating to show that the mixing of two cereals, or the mixing of a cereal and a legume, leads to an increased total weight of grain per acre. Where cereals are grown as bread corn the disadvantages of mixing them are obvious, the chief one being the difficulty (or impossibility) of separating the different grains at threshing. This, however, does not apply to beans or peas mixed with a cereal, as the separation can be made quite easily. Where stock feed is the object, the mixing of cereals and legumes has much to recommend it, and the practice has long been popular in various parts of the country.

It may be claimed for mixed corn that it is, first and foremost, an insurance against loss, for insect and fungus pests and fluctuations in the weather are unlikely to affect adversely all the plants. Then there is the probability of a greater weight of grain per acre solely on account of mixing the seeds. Cereal mixtures with beans or peas or vetches seem to

benefit the leguminous constituents in a remarkable way, quite apart from the support which the upstanding cereal or bean gives to the peas or vetches. Mixtures of cereals with oats or vetches can, in case of necessity, be turned into hay or silage instead of being allowed to ripen in the usual way. A well-grown mixed corn crop is also a suppressor of many kinds of weed, while the range of soils suited to these mixtures is very wide.

Dredge corn is a mixture of cereal grains, while mashlum is a mixture of cereals and leguminous grains.

Oats and barley, or oats, barley and wheat can be mixed in almost any proportion for dredge corn, though the amount of wheat included is usually small.

Examples of mashlum mixtures are set out below, though it must be remembered that little experimental work has been done so far on the question of the best proportions of the various cereals and legumes.

EXAMPLES OF SEEDS MIXTURES FOR MIXED CORN
(cwt. per acre)

	Wheat	*Barley*	*Oats*	*Beans*	*Peas*	*Vetches*
1	—	1¼	—	—	½	—
2	—	—	1¼	—	½	—
3	¾	—	¼	1½	—	—
4	—	⅓	½	½	¼	¼
5	—	—	1	1½	—	—

Where beans form a considerable part of a spring-sown mixture it is a common practice in many districts to plant the beans first, and to broadcast and harrow in the oats two to three weeks later. Peas may also be planted in spring over a winter-sown crop of beans.

ARABLE SILAGE CROPS

It is the practice in some parts of the country to sow mixtures of cereals and legumes for making into silage. The higher the proportion of legumes the richer is the resultant silage in protein, but a proportion of cereal is usually essential to keep the crop upright, and to facilitate cutting. Typical mixtures for arable silage have already been given in the section dealing with vetches, for vetches are the best leguminous silage plant we have. An alternative mixture is 1 cwt. oats, ½ cwt. beans, ½ cwt. peas. Actually, a good ryegrass and clover ley forms as good an arable silage crop as anything else. It is very desirable to cut cereal-legume silage crops quite early, preferably just as the legume is coming into flower. In this way a more nutritious silage is produced than if cutting is delayed until the legume is well podded.

CHAPTER 4

WEATHER IN RELATION TO FRUIT AND VEGETABLE CROPS

By D. A. Osmond.

The choice of a locality for growing hardy fruits and vegetables is determined by many factors, among which climate is important and indeed, the cultivation of these crops is usually not commercially profitable unless climatic conditions are such that the crops grow without a severe check and reach maturity at the desired times. While crops may be profitable in one district because of suitable weather conditions at a given time, in another they may be less so if the same conditions occur at a less favourable period for their growth.

The climate of Great Britain, which, for variety, can scarcely be matched in any other part of the world, is largely determined by the fact that Great Britain is situated near the shores of the European continent. To understand the vagaries of the climate, it must be realised that Great Britain is an area of continuous conflict between warm, moist winds from the Atlantic Ocean and cold, dry winds from high latitudes with occasional hot, dry winds from the central and southern parts of Europe. The contrast between the elevated western districts of Great Britain and the lowlands in the east is reflected in differences of rainfall and temperature. In spite of the many variations, however, the range of conditions allows of the cultivation of hardy fruits and vegetables over a large proportion of England, whilst many vegetables can be grown successfully in Scotland and Wales, though fruit growing is restricted in both these countries, particularly in Wales.

Distribution of Fruit and Vegetable Growing Areas.—The main commercial areas of tree fruit production in England are Kent, the West Midlands, Devon, Somerset, Norfolk, Essex, Cambridge and the Isle of Ely, and although the climate of Scotland does not lend itself to extensive tree fruit growing, plums are grown for market successfully in the Clyde Valley. Soft fruits are grown mainly in Norfolk, Kent and the Isle of Ely, with smaller acreages in Essex, Worcester, Hampshire, Hereford and the South-west counties. In Scotland, the Lanark area is as well known for its strawberries as the Strathmore district is for its raspberries.

Owing to the perishable nature of many vegetables and the desirability of consuming them as fresh as possible, the production areas, in many instances, were determined initially by the position of the large consuming centres. Thus, the vegetable industries in Kent, Essex,

Middlesex, Surrey and Bedford were developed to supply London. Similarly, Lancashire and Cheshire served the Manchester-Liverpool region, and Birmingham was supplied largely by Worcestershire. In Scotland, the produce of the Clyde Valley and Midlothian was distributed in Glasgow and Edinburgh.

These are not the only production districts supplying these centres today; others have been found suitable and, with improved methods of transport, produce is now sent from the Isle of Ely, Huntingdon, the East Riding, Norfolk, Holland, Hampshire and Cornwall. The producing districts of the Midlands send vegetables to the industrial North and the produce of Kent can be seen in the markets of Glasgow. Cornwall and Devon send away large quantities of winter broccoli, spring cabbage and early potatoes to various consuming centres throughout Britain. The main production areas of asparagus are Worcester and Norfolk, while brussels sprouts are extensively grown in the counties of Bedford and Worcester.

Glasshouse crops are largely grown for local consumption, but the large glasshouse areas in Hertford, Essex, Sussex, Kent, Middlesex and Surrey function as exporting areas for London and the larger industrial districts. Manchester and Liverpool obtain considerable amounts of such produce locally. There are also large acreages under glass in Norfolk and Holland.

Fruit Growing and Climate.—In selecting a district for fruit growing, climate must be considered as of prime importance since it may prove a decisive factor with regard to cropping, quality of produce and costs of production, points which are greatly affected by spring frost, sunshine and rainfall. Earliness is not in itself all-important, and districts may be equally successful in contributing to supplies of early, mid-season, or late produce.

Rainfall is very important and in Great Britain, a wide range of tree fruits cannot be grown easily if the rainfall is more than 35 inches per annum, whilst at above 40 inches success is very problematic. It is for this reason mainly that Wales and many districts in the West of England are unsuitable. In Scotland, the high rainfall is also a limiting factor but, in addition, summer temperatures may also be too low to give suitable quality. Winter temperatures in England are seldom low enough to cause damage to trees (e.g. bark splitting) but are sufficiently low to ensure a suitable rest period for the trees, for which at least forty-three days with temperatures below 45° F. are necessary to ensure normal bud-break in the spring.

For the production of good quality dessert apples and in order to obtain a good "finish" one of the main requirements is plenty of sunshine. The percentage frequency of days with more than half the possible sunshine is at a maximum in June, declines in July, but rises again to a second but lower maximum in September. Also the further north and the further from the coast, the fewer the number of hours of sunshine per

day. Therefore dessert apple growing is largely concentrated in the east and south-east of England.

Culinary apples do not require as much sunshine to bring them to a marketable state and can withstand wetter conditions, especially if they are grown in grass. This class of fruit can thus be grown successfully over a much larger area than the dessert sorts, as for example, in the wetter and less sunny parts of the west and north of England and Scotland.

Gales are generally credited with causing damage to tree fruits, but it is possible that sudden gusts of wind are a more frequent cause of loss than a continuously blowing strong wind, although the latter is not without its effect on tree growth. It is stated that "gusts exceeding 54 m.p.h. are by no means uncommon even in inland districts" (Bilham). The data indicate that the number of gales is at a minimum in June, increases slightly until August, when it remains constant and at a low value until it begins to increase again in October. This would indicate that sheltered situations away from the coast should be chosen when possible, both to minimise the danger of gale damage and to avoid injury caused by the salt sea spray which can be carried considerable distances inland. Fortunately, the number of days with hail in the month seems to be at a maximum in March and at a minimum during those months when fruit crops are likely to be damaged. Since falls of hail are free quently associated with thunder, it is well to avoid a district which had a reputation for "breeding" thunderstorms, particularly in summer.

One of the difficulties in apple growing is the control of diseases, particularly scab and canker, both of which are more prevalent in regions of high rainfall. Canker in some districts may preclude the growing of many choice varieties, and although preventive measures can be taken against scab, high rainfall may render control both difficult and expensive and, in extreme cases, uneconomic.

Certain varieties of plums can be grown successfully where dessert apples are less satisfactory, because they can stand somewhat wetter conditions. Thus, Victoria plums are grown successfully as far north as the Clyde Valley. With plums, however, a high rainfall greatly increases the liability to attack by Brown Rot.

An important climatic requirement for the successful production of cherries is a low rainfall during the period March to July, from blossoming until the fruit is picked, and their culture becomes hazardous in districts which receive more than 30 inches of rain per annum. A dry July is particularly important, since too much rain at that time may cause splitting of the fruit and ruin its market quality.

Pears require a similar climate to that necessary for dessert apples, and a high amount of sunshine is essential to ensure satisfactory commercial quality.

One of the greatest hazards in fruit growing is spring frost. The damaging frosts, which often occur in March, April and May, originate in two ways; there are those caused by cold wind—"wind frosts" or

advective frosts, and those which arise from the downward streaming and subsequent ponding of cold air under almost calm atmospheric conditions—radiation frosts. Cold north-easterly or north winds blow during about one day in eight in April and May, and if the cold spell persists, fruit blossoms may be frosted. It is not possible to guard completely against wind frosts, but it is obvious that exposed situations are liable to suffer most and that some degree of shelter from the north and north-east may be desirable.

Radiation occurs on any night when there is no cloud and little air movement. Under these conditions, air at ground level is cooled indirectly by radiation and, being denser than warm air, tends to flow slowly down slopes and to drain to lower land. If there is no exit from this lower area, cold air will collect, sometimes to a sufficient depth to submerge trees in a still body of cold air. If air temperatures during the day are low, those during the night, when radiation preponderates, will be lower and may be low enough for frost damage to occur. A great deal, therefore, depends on the choice of situation; gentle slopes or isolated low hills are satisfactory, for even if there is an adjoining area acting as a source of cold air, this may drain away. Tall, thick trees may help in directing cold air away from the situation, but any similar line of trees etc. lying across the air-stream will restrict air movement and should be removed. Since arable land loses its heat by radiation less quickly than grassland, it is an advantage if the situation has arable land around it. The mouths of valleys through which a cold air-stream may be directed on to the situation should be avoided. In practice it is found that damage from radiation frosts is much more frequent than from wind frosts, hence the importance of avoiding so-called "frost-holes."

The climatic requirements of soft fruits are similar to those of tree fruits, but earliness may be a more important factor, e.g. strawberries. The main crops of soft fruit in England are grown extensively in Kent, the Isle of Ely, Norfolk and the West Midlands, where rainfall is less than 30 inches per annum. The Tamar Valley, Cheddar and South Hampshire are well known as important early districts. While earliness may result solely from a more genial climate, in these districts and many other small localities, the local climate is quite distinct from the generally prevailing conditions, owing to the configuration of the land.

Vegetable Growing and Climate.—In the extensive growing of vegetables an effort is made to control frost, rainfall and temperature, by choosing sheltered spots in favoured districts and by the use of frames and cloches which protect the growing plants.

The production of early crops on a large scale requires particular climatic conditions such as the mild winters of Cornwall which favour the production of early broccoli. By regulating the moisture and temperature, either by the use of frames or greenhouses, young plants can be brought on and planted out early, as in the Vale of Evesham, where,

with mild winters and sufficient sun, cauliflowers are raised under glass and planted out to take advantage of the early summer growing conditions. It is essential that the rainfall should be adequate. But with too much rain, weeds are liable to smother the young plants, while if droughty conditions prevail the plants receive harmful checks.

Vegetables are tolerant of a wider range of climatic conditions than tree fruits and are, therefore, more scattered in their distribution. Cabbage provides a long harvest of good quality heads when temperatures are between 55° and 60° F. but above 70° F. growth is poorer. This applies to most brassicæ, but cauliflower is more exacting, and, while growing best between 60° F. and 70° F. is less tolerant of extreme heat or cold, strong winds, excessive rain or an acid atmosphere. Spinach, beet, peas, potatoes, carrots, lettuce and celery have optimum growing temperatures between 50° F. and 70° F. while tomatoes do not grow successfully where temperatures do not rise above 65° F. Temperatures over 80° F. during a day or so impair the value of canning peas, and at the other extreme, their blossoms and pods may be seriously damaged by a slight frost.

Frost is of less importance in vegetable growing than fruit growing and generally it only temporarily checks the growth of plants. The effect of a vegetable crop may be to trap warm air, and cold air may be kept sufficiently above the crop as not to cause damage.

Earliness may be of great importance and, in areas with mild winters, spring cabbage and winter broccoli can be over-wintered with little risk, and mature early.

Glasshouses and Climate.—The essential object of a glasshouse is to provide controlled temperatures and water supplies, and while natural climatic conditions must be considered, they are obviously of less importance than for outside culture. Since earliness is a prime consideration, glasshouses should be so sited as to receive the maximum amount of sun, and the bottoms of steep-sided valleys should be avoided as the shadows cast may materially reduce the number of hours of sunshine.

Where the grower is dependent on wells or small local supplies for water, care must be taken to see that such supplies do not fail at any critical period.

The concentration of glasshouses in southern England is partly due to the high number of days with sun compared with more central or northern areas. It must also be remembered that the quantity and quality of sunshine is considerably affected over a large area by the smoke cloud from a highly industrialised region. The cloud from the Black Country reduces the number of hours of sunshine in the adjacent areas to the east and north-east, and a similar effect caused by the London smoke cloud is noticeable in the Lea Valley.

Distribution of Rainfall and Temperature.—Statistics clearly show that most of the fruit and vegetable crops are grown in the south and south-east of England, and it is of interest to examine the climatic

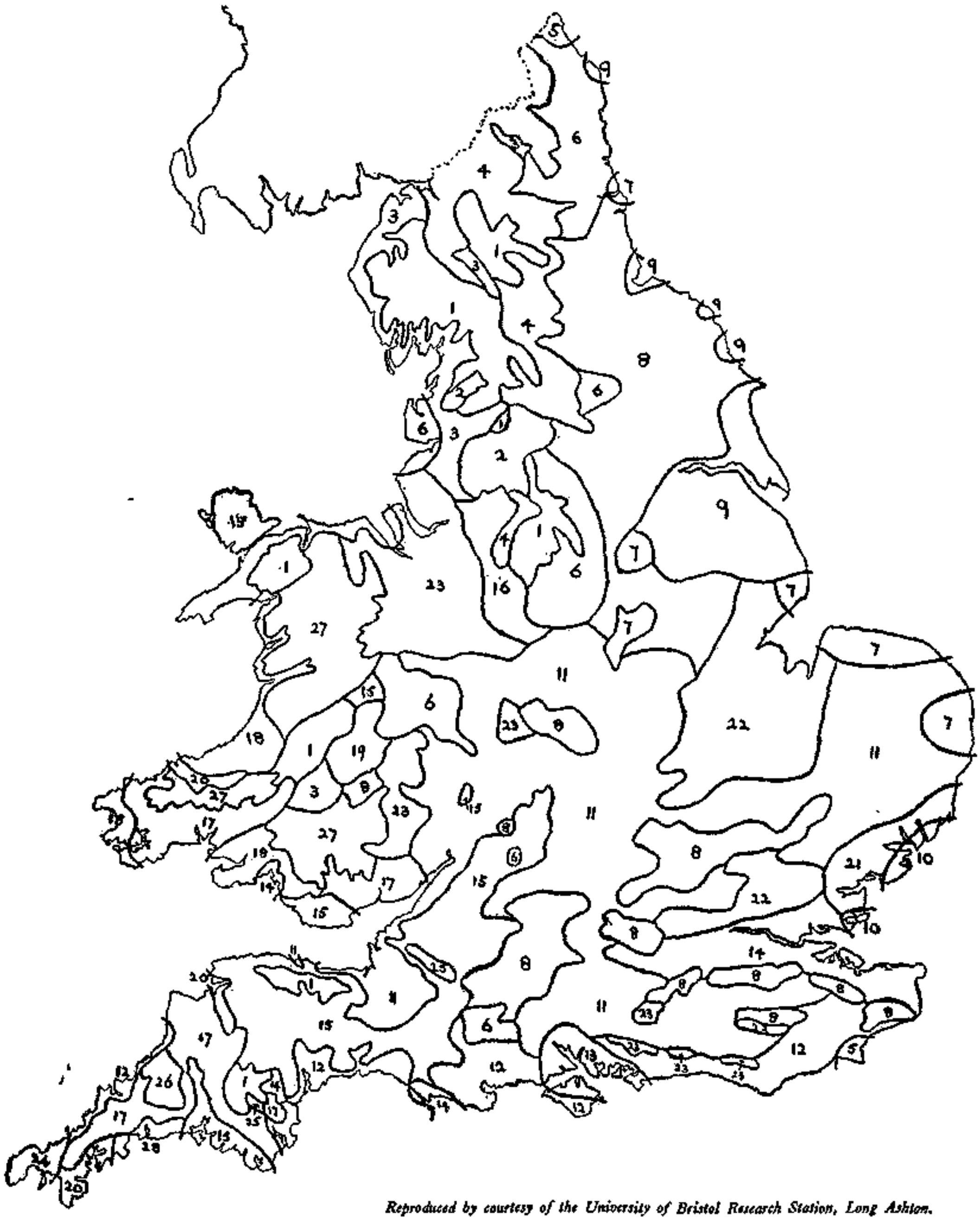

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FIG. 4. MAP SHOWING WEATHER REGIONS (SUMMER MONTHS) OF ENGLAND AND WALES

RAINFALL AND TEMPERATURES
(See Map, Fig. 4)
Reproduced by courtesy of the University of Bristol Research Station, Long Ashton.

Region No.	March	April		May		June		July		August		September	
		Rain.	Temp.	Rain.	Temp.	Rain.	Temp.	Rain.	Temp.	Rain.	Temp.	Rain.	Temp.
1		W	C	W		W		W		W		W	
2			C			W		W		W		W	
3			C					W		W		W	
4			C					W		W			
5	COLD MARCH	D	C	D	C								
6			C							W			
7		D	C										
8			C										
9		D											
10			C	D	C				H		H		
11													
12			C										
13			C						H		H		
14			C								H		
15			C							W			
16			C					W		W			
17			C					W		W		W	
18			C			W		W		W		W	
19	WARM MARCH		C	W		W		W		W		W	
20			C							W		W	
21		D	C										
22		D											
23										W			
24										W		W	
25		W				W		W		W		W	
26		W		W		W		W		W		W	
27		W	C	W		W		W		W		W	
28								W		W			

W indicates mean monthly rainfall of 2·89 in. or more.
D ,, ,, ,, ,, ,, 1·49 in. or less.
H ,, ,, ,, air temperature of 62·5° F. or more.
C ,, ,, ,, ,, ,, ,, 48·8° or less.

The blank spaces indicate average conditions, i.e., the mean monthly rainfall and air temperature fall within their respective limits. Regions 1-10 have a cold March and regions 11-28 have a warm March, i.e. mean monthly air temperatures below and above 42° F. respectively.

conditions in England and Wales which may account for this. It is not reasonable to expect successful culture of fruit or vegetables if the locality is subject either to an excess or a deficit of either rain or warmth at an inopportune season, and these are the main weather factors to be considered. Maps showing the annual and seasonal distribution of rainfall and temperature are obtainable, but it is not easy to visualise from these the combinations which produce favourable or unfavourable conditions.

Maps combining rainfall and temperature can be made which are much more helpful. In making such a map it may be assumed that after winter rains most soils contain sufficient moisture for plant growth, and that seeds can germinate in them when the air temperature has risen to about 42° F. i.e., air temperatures which occur in March. The main growing and harvesting months are from April to September, and by calculation from the mean monthly rainfall and air temperature data, it can be concluded that certain "regions" are, on the average, significantly wetter or drier, and at the same time, hotter or colder than the monthly averages during this period. This average monthly rainfall for England and Wales is 2·19 inches and areas with a rainfall of 2·89 inches or more in a specified month may be classed as "wet" and with a rainfall of 1·49 inches or less as "dry." Similarly the average monthly air temperature is 55·7° F. and "hot" refers to temperatures of 62·5° F. or more and "cold" to temperatures of 48·8° F. or less. The map (Fig. 4) and the accompanying table (page 157) show the distribution and character of climatic regions on this basis for England and Wales. Twenty-eight regions are shown, of which nineteen occur in the counties where fruit and vegetables are grown commercially on a large scale. The regions of greatest interest are regions 6 to 17 inclusive and 21, 22 and 23, since most of the others have at least four "wet" months. A consideration of the characters of these regions indicates that while regions 9, 11, 12, 16, 22 and 23 are suitable for vegetable crops, regions 6, 7, 8, 15 and 21 are somewhat less suited, on account of a tendency to "lateness" in March and April. Regions numbered 10, 13 and 14, in spite of apparent lateness, provide rapid increases in temperature (from about 49° F. in April to 62° F. and over in July and August) and such regions would be suitable for fruits or vegetables requiring quick-growing conditions. Devon includes some of region 17 and it may be that cider fruit (the main crop) is more adapted to the conditions than are the dessert or culinary varieties. Tree fruits appear to be grown mostly in regions 11, 12 and 14, while both regions 11 and 21, particularly the latter, are favoured for vegetables.

While the map must be regarded as only an attempt to show climatic regions, nevertheless, it indicates districts in which the development of fruit or vegetable growing might be considered, provided the other requirements of site and soil are favourable. Thus, region 14 appears around Swansea, Weymouth and to the north-west of Newton Abbot—

areas which might provide suitable land for the production of early vegetables. Region 15, though somewhat less suitable, covers considerable areas in Wales, and the extension of region 23 into the Clwyd Valley in North Wales might provide further areas for the cultivation of fruit and vegetables to be marketed in the nearby holiday resorts.

CHAPTER 5

VEGETABLE CROPS ON THE FARM

By A. H. Hoare

During the last twenty years the growing of vegetable crops on the general farm has increased considerably. Many factors have played a part in this development, but from the economic viewpoint it is not to be concluded that the ordinary market-garden has been superseded or has had its day. The market-garden, no matter what its size, is concerned mainly with the production of all kinds of vegetables for a local market. The farm is concerned mainly with the production of special crops for distant markets and for various types of manufacture such as canning, pickling, freezing, drying and dehydration. The economic factor that seems to have influenced the expansion of vegetable growing on farms was the cereal market slump during the 1928-38 period, when many farmers turned to cash crops of this type.

Apart from these considerations, however, certain important factors operate in favour of the farm. For example, the disease and pest factor has probably been concerned with the transfer of some crops, such as carrots, from the market-garden (where the carrot fly can develop to serious proportions) to the farm where clean land, remote from centres of infestation, is available. The cabbage aphis probably was concerned in dispersing the Brussels sprout crop further afield.

While the fertility factor is another important one, it is not so important as some people believe, because a market-gardener operating a large acreage can maintain his land in a reasonable condition of fertility with the aid of livestock manure and composting. He is not so well placed as the farmer who goes in for ley farming on a wide rotation, a system of land treatment which preserves not only soil fertility but *soil structure.* Soil structure is a very important factor in the successful cultivation of many vegetables, notably the Brassica and leguminous crops, and leys and course cropping play an important part in the maintenance of this condition.

Soil and climate are other important factors in vegetable growing which frequently operate to develop cropping on farms. For example, the peaty fenland soils, being rich in nitrogen and of high moisture-holding capacity, are unsurpassed for celery growing, and are also good for carrots, beet, potatoes and other vegetables. Our Fen and "Moss" lands carry large acreages of such crops. A mild climate is essential for crops like winter cauliflower (broccoli), and in consequence, farms in the milder part of England (Devon and Cornwall) are much given to growing crops of broccoli to send all over the country.

The manufacturer, particularly, likes to have his vegetables for processing grown on the farm, for he can select the farms at a convenient distance from the factory, and can count on prompt attention to the work of cultivation and harvesting at the proper time.

There is no question of the farmer-grower of vegetables ousting or displacing the market-gardener, any more than the latter has dispossessed the intensive market-gardener. In the present-day scheme of things all three types of production operate together to the benefit of the consumer.

The ordinary farm is handicapped in some respects. As a rule it has not at its disposal the efficient irrigation system now so prominent a feature of well-equipped market-gardens. It may lack also the skilled labour which some vegetable crops need to ensure success. On this account the farmer should choose those crops which are less affected by periods of drought and which call for non-specialist labour. For example, crops of autumn and winter cabbage instead of crops of summer cabbage; winter cauliflower (broccoli) instead of summer cauliflower. Salad crops, such as lettuce, endive and green onions, are best left to the market-gardener because they require skilled handling. The same remark applies to dry bulb onions, and to leeks.

Finally, the fact that many vegetables need a strong labour force for harvesting or gathering the crops, should be mentioned. Most farmers are acquainted with the labour force required for harvesting the potato crop. The position is much the same for green peas and beans, especially peas, a crop which has to be picked quickly when ready. Such crops cannot be dealt with by the normal labour force of the farm. Most Brassica crops, except perhaps Brussels sprouts, can be gathered without extra help. Celery, if the crop is washed and crated in the modern way, will call for extra hands. Extra labour may also be required at planting time, even if transplanting machines are used. Therefore, farms which are not well situated for obtaining the extra labour when required, especially at crop harvest, should leave many vegetable crops alone.

To sum up, the best types of vegetable crops for the ordinary farm are as follows:

Root Crops.—Carrots, red beet, winter turnips, swedes, parsnips.

Brassica Crops.—Cabbage, Brussels sprouts, broccoli and kales.

Leguminous Crops.—Green peas, canning peas, dried peas.

Salad Crops.—Celery.

THE BRASSICA CROPS

Brassica crops of all kinds are successfully grown on farms, for they thrive on a wide range of soils and respond to the soil conditions created by a good farming rotation, especially when it includes a ley. The crops most successful under average conditions are spring cabbage, autumn and winter cabbage, Brussels sprouts and broccoli. The farmer must decide

whether his local conditions of soil and climate are good enough for crops of summer cabbage, summer and autumn cauliflower and spring greens. Cauliflowers for pickling, a late summer crop, are grown successfully on selected farms, usually on a contract basis.

Soils.—Loamy soils of good quality are the most suitable for the Brassica crops, for such hold moisture and organic manures for long periods. Organic manures are of importance for these crops, especially for winter cabbage and savoys, which often fail to finish well, i.e. heart up satisfactorily, when the soil lacks organic matter. The grower has only to treat half a field of winter cabbage with fertiliser and half with dung to show this.

Spring Cabbage.—This crop is grown from seed sown in the July-August period, the plants being transplanted in September and October to stand the winter in the open land. If well-drained land is chosen, and the soil is firm and not too fine on the surface, the plants will winter successfully.

The spring cabbage crop is best grown on land well manured for a preceding crop such as potatoes. After that crop is removed the land should be given an application of a mixture consisting of commercial fertilisers such as superphosphate and sulphate or muriate of potash and a quantity of an organic such as hoof, meat and bone or fish meal. For example, an average dressing after a dunged crop would be:

Hoof and Horn	8 cwt.	per acre
Superphosphate	4 „	
Muriate of Potash	1½ „	

The land is prepared for planting by a light ploughing or discing followed by harrows and, if necessary, the roller is used to obtain a firm, but not smooth, surface condition.

The plants are raised in specially prepared seed-beds, from 6-8 lb. of seed being allowed per acre of seed-bed. It is best for a grower to raise his own plants. An average planting distance for this crop (full size varieties) is 24 inches (row width) by 18 inches (plant spacing), which requires 14,600 plants per acre. Roughly the same quantity can be used with rows of 30 inches and plants spaced 15 inches in the rows, a method which gives more room for tractor cultivation. Smaller varieties may go a little closer in the rows, but well-spaced rows are a useful aid to rowcrop cultivations.

Transplanting may be done by hand or with transplanters; many prefer the dibber for spring cabbage as the firmness of the land is not disturbed. All planting should be completed by the last week of October or a winter "stand" will not be secured.

Spring cultivations and applications of stimulating fertilisers such as nitrate of soda, sulphate of ammonia or potassium nitrate are invaluable to bring this crop along early and induce quality.

The spring cabbage crop is often marketed in a semi-hearted condition if the demand is good. The field should be "cut over" once or twice a week, selecting the heads in uniform condition. Bags containing an equal weight, and boxes and crates containing a certain number of heads, are mainly used for marketing spring cabbage.

Summer Cabbage.—Crops of summer cabbage are marketed mainly during June and July, being grown from plants raised (according to variety used) from seed sown either in the previous August and wintered in the seed-beds, or under lights in February or early March. The pointed-headed Leeds Market and Winnigstadt types may be sown in August and the round-headed Primo types in February or March.

The land for these crops of cabbage should be ploughed and manured in the autumn so that the plants go out on well-consolidated soil. As it is difficult to grow good crops of summer cabbage on land lacking organic matter, at least a moderate amount of manure or compost should be applied before the land is ploughed. A complete fertiliser mixture should then be applied before planting.

To permit of mechanical rowcrop cultivation these crops should be given fairly wide rows when transplanted. A row spacing of 24 inches and plant spacing of 18 inches is satisfactory for medium-sized varieties. It is important to keep the land well cultivated and free from weeds after planting to ensure the rapid growth which makes for quality in the crop.

Autumn and Winter Cabbage.—These crops, which are marketed from August to February, are important sources of supply, the hardier varieties often being in great demand in January and February when other green vegetables are scarce. Experience is required, however, in choosing the varieties to suit each district, and in sowing and planting at the correct times.

The seed for these crops, according to variety and district, is normally sown during April and May, and transplanting is done from May to mid-July. Few plantings after mid-July are likely to give successful yields, for it is essential that these crops should heart up properly for marketing. They will not heart if the planting is late, and it is difficult to sell this class of cabbage unless it is well-hearted.

Experienced growers hold the view that, to finish properly, these cabbage crops must be grown on manured land. This applies particularly to winter cabbage and savoys which grow better on manured land when the winter sets in. The land should be dressed with dung or compost at rates of 10, 15, or 20 tons per acre, according to its condition, the only exception being a ploughed-out pasture or long ley. Short-ley land should have the lighter application of manure. Where manure is scarce lighter dressings, supplemented by a complete fertiliser mixture, or meat and bone, hoof, or sewage sludge, may be used. Potash has a good effect on these crops, hardening the growth to withstand frost, and imparting colour. Whenever possible the land should be dressed prior to planting with a fertiliser

mixture containing potash. When the crops are beginning to form hearts, a light top-dressing of a nitrogenous fertiliser, e.g., 1 cwt. per acre of nitrate of soda, is of assistance. Nitrate of potash is also very effective as a top dressing in the autumn while the soil is still warm.

Marketing of Summer, Autumn and Winter Cabbage.—These crops are marketed in various ways. The heads are cut as they mature to an even size, and are lightly trimmed. The heads should be hard and dark green in colour. Growers conveniently situated often deliver cabbage to the markets loose in lorries. They are also packed in bags, nets, coir mats, wood boxes and crates, 20 large heads or 24 to 30 small ones, weighing 60 to 70 lb. being a marketing unit of general convenience.

Brussels Sprouts.—As normally this crop is on the land for a full nine months, it cannot be grown as a catch crop or be worked in after an early crop. Brussels sprouts need a full period of growth so must be planted early, by the end of May at latest, to ensure success. March and April plantings are commonly made to obtain early crops of sprouts.

The land should be prepared well in advance of planting to ensure the consolidation the crop requires, and if a ley or old pasture is to be used it should be ploughed in the previous autumn and *not* in the spring. Deep ploughing is required and a subsoiler should be used if a pan exists. If the land's fertility has been worked out by several straw crops, a heavy application of farmyard manure must be given for the sprout crop. Following a dunged potato crop, or leys, the sprouts may be grown satisfactorily by using organics, such as shoddy and soot, together with a complete mixture of fertiliser, both potash and phosphate being important in growing sprouts of good quality.

Transplanting is commonly practised, the earliest plantings being made with autumn sown plants, or plants raised in frames from seed sown in January and February. The bulk of the plantings are made with plants raised from seed sown in open seed-beds in March. An acre of seed-bed is required to provide plants for from 16 to 20 acres, and 6 lb. of seed should be allowed.

Brussels sprouts are usually planted 3 feet square, though some growers have the rows 3 feet 6 inches apart for ease of cultivation, picking, etc. A square plant is easier to mark out for hand planting. Mechanical transplanters do the planting successfully but cannot keep to the square line-out. For sprouts top dressings should be very carefully used, otherwise "blowers" may result. Soot is much used as a top dressing, being considered not so forcing as other nitrogenous fertilisers. Chilean potash-nitrate is also a useful fertiliser for top dressings.

Marketing of sprouts begins in late August and continues throughout the winter. The fields are picked over repeatedly to secure the sprouts as they mature. Finally the tops are removed and marketed as "sprout tops," and still later there may be a market for "sprout greens" before the stumps are removed from the land. Many growers feed off the stumps with sheep

as soon as the tops are marketed, so freeing the land early in the year for a succeeding crop. The stumps should be *cleared from the land*, not ploughed under, and should be destroyed or buried.

Sprouts are marketed in bags, boxes, crates and nets containing various weights. They should be graded and trimmed of waste leaves to make a good sample. There is usually a trade for both large and small sprouts. Yields of sprouts usually range from 3 to 4 tons per acre.

VARIETIES OF CABBAGE FOR FARM CULTURE

Spring crops: Harbinger, Wheeler's Imperial (small-sized types), Durham Early Early Market (medium-sized types), Clucas's First Early Market No. 218, First and Best, Flower of Spring, Early Offenham, Early Evesham (large-sized types).

Summer crops: Primo, Golden Acre, Winnigstadt, Leeds Market.

Autumn and Winter crops:

CABBAGE—Feltham Drumhead, Glory of Enkhuizen, Utility, Christmas Drumhead, January King.

SAVOYS—Ormskirk Early, Ormskirk Medium, Ormskirk Late, Ormskirk Extra Late, Alexander's Late, Omega, Sutton's Rearguard.

VARIETIES OF BRUSSELS SPROUTS

Early crops: Rous Lench, Cambridge No. 1.

Mid-season crops: Evesham Special, Harrison's XXX, Cambridge No. 3.

Late crops: The Darlington, Clucas's Latest and Best, Clucas's Favourite, Cambridge No. 5.

NOTE.—Owing to the genetical instability prevailing throughout the varieties of *Brassica oleracea*, selected strains of the varieties mentioned should always be grown.

Winter Cauliflower or Broccoli.—This is a crop well-suited to the mixed farm in the south, south-east and south-west of England, particularly Devon and Cornwall. In the last-named county it is estimated that some 7,000 acres are now grown annually. The crop is also successfully grown in Kent, Lincolnshire, Dorset, Hampshire, Isle of Wight and Sussex.

Land.—It is recommended that a minimum area of 5 acres be used for this crop though beginners might make a trial planting of 2 to 3 acres.

A medium loam soil of good average depth should be chosen on a gentle slope, well drained, but not liable to drought, avoiding fields where Finger and Toe (Club Root) has been known to occur within recent years.

As rabbits and hares are particularly fond of cauliflower plants, both the seed-bed and the field should, where necessary, be rendered rabbit-proof. A fence of 4-foot wire netting, 1½-inch mesh, with the bottom 6 inches buried in the ground and turned outwards, forms a sound protection.

Place in the Rotation.—The best place for the crop is following a ley; failing this the crop may replace spring corn following a well-manured

root crop. The crop may also replace a root crop following corn, where a half-fallow is required for cleaning purposes.

Preparation of the Land.—The land should be ploughed in early autumn. Ley land should be scarified by means of disc harrows or a cultivator before ploughing to assist the breaking down of the turf. Ploughing should be as deep as possible, and the land left to consolidate thoroughly. While a later surface working to destroy weeds and obtain a good tilth is essential, care must be taken not to disturb the turf. The land should not be cross-ploughed.

As the crop continues to develop throughout the winter months, it is essential that ditches and all outlets of land drains should be in working order.

Manures.—Where a long ley of good quality is used no dung need be applied, and artificial nitrogenous manures should be used with care. On land of one-year leys and on poorer land a light dressing of dung will be beneficial. Following a corn crop a minimum of 20 tons of rotted dung per acre should be ploughed in, care being taken not to disturb this in subsequent cultivations. Firm land in which organic matter is decomposing is essential as a rooting medium for this crop.

For satisfactory growth an adequate supply of lime in the soil is also essential. Calcareous seashore sand is much used in Cornwall for the broccoli crop; elsewhere ground chalk is used.

Fertilisers.—A complete fertiliser is used by some growers with success. Others use a dressing of 3 to 4 cwt. of basic slag, plus 3 cwt. sulphate or muriate of potash per acre. Fertilisers should be lightly cultivated in, a week or ten days before planting. As the applications of lime, phosphates and potash should vary according to the soil, it is recommended that the National Agricultural Advisory Service be consulted in this matter. On no account should the crop be top dressed in the autumn as a soft growth leads to severe damage by frost. Top dressings when required are applied from January onwards. Nitrogenous fertilisers tend to produce soft curds, while potash tends to produce curds of firmer quality. The combined fertiliser, potash-nitrate, has proved a valuable top dressing for this crop.

Seed.—Seed should always be obtained from a reliable source, for useless strains of so-called "Roscoff" are on the market. Advice on sources of supply and reliable strains should be obtained.

The seed should be sown in an open field well away from hedges and over-hanging trees. The soil of the seed-bed should be well-worked down to a fine tilth. A good dusting of lime and an application of superphosphate at the rate of 400 lb. per acre, well worked into the soil, will assist both germination and the seedling growth. The seed should be sown thinly in rows 15 inches apart during the last week in March or the first week in April. Eight ounces of seed is sufficient to provide plants for an acre. Seed may also be sown broadcast in beds 4 to 5 feet wide—1 lb. of seed

A field of well-grown brussels sprouts.
(Photo by A. H. Hoare.)

Broccoli growing in Cornwall, showing Roscoff type.
(*Copyright Sutton & Sons, Ltd. Reading.*)

Growing green peas for market. Picking and bagging the crop.
(*Copyright Sutton & Sons, Ltd., Reading.*)

will sow approximately 6 square poles of seed-bed or a bed 327 feet long by 5 feet wide.

Sturdiness and uniformity of size of the plants at the transplanting stage have an important effect upon the yield and quality of the crop. Good plants are obtained by sowing thinly, and frequent hoeing between the rows stimulates growth and facilitates drawing. While the seed-beds should not heavily be manured, the land should be in a good condition from the humus standpoint.

Transplanting.—It is a general practice to mark out the ground in 2½-foot squares and plant where the lines intersect. This gives a good spacing for average growth and takes just over 7,000 plants to the acre. Some growers believe that a 3 feet by 2 feet spacing is preferable because, while still permitting some amount of cross-cultivation it affords better facilities for continuing cultivations between the rows later in the season, and also for banking up the plants more satisfactorily in August-September. This spacing takes 7,260 plants to the acre.

It is necessary to leave spaces unplanted with the main crop for "driving roads" through the field, so that when cutting begins the heads need not be carried any distance but are loaded direct. The "driving roads" should be left three rows wide and be spaced every sixty rows of the main crop. On larger fields, cross or intersecting roads may also be necessary. The spaces left for roads may be occupied with an early maturing crop, such as autumn cauliflowers. Veitch's Autumn Giant, Clucas's Majestic and Sutton's Dwarf Monarch are suitable varieties, being cleared before cutting of the main crop commences.

Where variation in size exists the plants should be graded so that all the plants for one field are of approximately the same size and quality. Planting should be done from the first part of June to the first week in July according to the district. Planting is done later in Devon and Cornwall than elsewhere. Where planting is delayed until after July 10, a serious reduction in the yield of good heads will occur. Transplanting may be done by hand with a dibber, a "planting iron" or mattock, or by a mechanical transplanter. With hand planting, holes are made sufficiently deep to take the plant up to the lower leaves and it is then made thoroughly firm by the dibber or, when using other tools, the heel of the operator.

Supplying.—If the field has been well prepared and the plants well grown, supplying (i.e, filling up gaps with fresh plants) should be unnecessary. Where necessary, however, it should be completed by mid-July, for after this date the operation is rarely successful.

Crop Cultivation.—The crop should be cultivated at least twice in each direction to keep down weeds. Some crops are banked, others are not. This practice depends on the district, the wetter districts requiring it and not the drier. Banking is usually done in August and is similar to the first moulding of a potato crop, the moulding plough also being used for this operation. Except on steep fields the ridge and furrow should generally

run in the same direction as the slope (not across it) for drainage; the banking being done just before the plants touch in the rows. The plough is set to leave a flat bottom to the furrow to facilitate walking through the crop at cutting time. The whole object of banking is to remove excess water from the soil, for the crop is sensitive to conditions of excessive moisture. Thus it assists in maintaining regular growth and good health in the plants.

Cutting.—Heads should be cut as soon as they are ready, a large, sharp butcher's knife being the best for the job.

Trimming, Grading, Packing and Marketing.—As it is impossible to give detailed directions for carrying out these operations, advisory visits to growers by members of the N.A.A.S. staff can be arranged and up-to-date methods of grading, packing and marketing demonstrated on the spot. Approximately 230 crates are required per acre for marketing the crop; arrangements for the purchase of these should be made well in advance of requirements.

The field is cut over frequently. A good system is for the cutters to work in pairs, one man cutting and the other carrying. The cut heads are placed straight into the wicker carrying skip or crate fastened to the carrier's back (*See* Plate facing page 167). When full the crates are taken to the carts and unloaded. The carts take their loads to the grading and packing shed where the heads are graded for size and quality, the amount of foliage left on after trimming depending on the grade.

Modern Varieties of Broccoli.—During the last twenty years persistent efforts have been made to improve the varieties of broccoli suitable for cultivation in England, using the French Roscoff and Angers types as a basis of breeding. This task involved the production of strains which would withstand the climatic conditions of different districts. For example, a strain which does quite well in the south-western counties of Devon and Cornwall would most probably fail in the south-eastern counties because of the more rigorous winter climate.

At the Cambridge Horticultural Research Station attention was directed to the problem of obtaining strains of hardy constitution and giving good foliage protection to the curd. At Seale-Hayne College, strains suited to the milder conditions of the south-west were mainly the objective. The result of this work is a short but useful list of strains of broccoli suitable for maturing in the early months of the year when the demand is keen. These are:

Cambridge	5X	maturing	February-early March.
"	426	"	" " "
"	3X	"	end of February-March.
Seale-Hayne	B1	"	January-February.
"	A6	"	January-early February.
"	No. 3	"	February-March.
"	DK7	"	March.
"	No. 5	"	April-May.

Broccoli in Cornwall.—In the broccoli-growing district of Cornwall a full range of cutting extending over several months is obtained by planting a selection from the following:

Walcheren	September-October
Michaelmas White	November-December
Veitch's Self-protecting	November-December
Tonkin's November Heading	November
Tozer's December Heading	December
Early Roscoff	December-January
Seale-Hayne A.6.	January-February
Selected Roscoff No. 1	January-February
Superb Early White	January-February
Seale-Hayne B.1. (Roscoff type)	January-February
Morse's January (Roscoff type)	January
Jeffrey's Roscoff	January
Morse's February (Roscoff type)	February
Selected Roscoff No. 2	February
Penzance Early White	February
Seale-Hayne No. 3	February-March
Selected Roscoff No. 3	March
Late Feltham	March-April
St. George	March-April
Seale-Hayne D.K.7 (Roscoff type)	March-April
Harding's Roscoff No. 4	April
Seale-Hayne No. 5 (Cross between Angers and Roscoff types)	April-May

Away from the south-west, where winters are less mild, the list of varieties should be modified to suit the climate. For example: Walcheren, Veitch's Self-protecting, Blatchford's Winter White, Snow's Winter White, Sutton's Snow-White, Early Feltham, Clucas's Lenten Monarch, Mid-Feltham, Clucas's St. George, Improved Leamington, Late Feltham, and Sutton's Late Queen would provide a successional list suitable for most climatic conditions. Several seed firms have developed hardy strains of Roscoff which will carry their leaf throughout an average winter, and these, together with the Cambridge hardy strains, may also be tried.

ROOT CROPS

The root crops generally grown for human consumption are carrots, turnips, red beet and parsnips. The ordinary field swede is also marketed when a demand exists. These crops can be treated as the normal root break in farming rotations, taking the place of sugar beet or mangel. The land preparation and general cultivation details are much the same for all root crops. It is a wise precaution to make prior arrangement with market salesmen before growing these crops, otherwise their disposal may be difficult to effect. If not required on the markets, however, most of these root crops can be fed to stock. In some winters, when green crops become scarce, roots such as turnips, swedes and carrots are in good demand on

the markets. There is normally a steady demand throughout the year for red beet of good quality.

In general, the crops grown on farms are of the late or storage class, the early and mid-season crops being grown mainly on market gardens. Some farmers, however, grow mid-season crops of carrots and red beet for which they usually have a pre-arranged market or a contract with a canning factory.

Soils.—Root crops of best quality are grown on various types of loam, though carrots are particularly successful on the lighter sandy soils and also on Fen soils such as are found in Suffolk and Cambridgeshire. Turnips do better under cooler conditions; they are a good crop in the midlands and in western districts. Heavy clays and light chalky soils are not so suitable for roots, and newly broken leys or old pastures should not be used.

Land Preparation.—A good seed-bed is essential for all root crops, particularly carrots. As soil moisture is an important factor in growing crops of quality the land should be deeply worked and firm, conditions which call for a stale furrow and the fine tilth obtainable only by adequate cultivations when the land is in correct condition for working. Many crops of carrots and red beet fail for want of a well-prepared seed-bed. Crop failures, especially with carrots and turnips, are also often due to a lack of lime in the soil.

Manuring.—Most root crops, and particularly carrots, should be grown without the use of dung. They are most successful when grown on land previously well manured. The use of a complete fertiliser should, however, not be omitted, both nitrogen and potash imparting quality to the crop, while phosphate assists seedling growth and plant development. While fertiliser mixtures vary according to the soil, in general 1 cwt. of sulphate of ammonia and 1½ cwt. of sulphate or muriate of potash per acre should be used. Superphosphate may vary from 3 to 5 cwt. according to the soil conditions. All fertiliser mixtures should be applied in the preparation tillage of the seed-bed from a fortnight to three weeks before sowing, and be well-worked in.

Sowing.—The seed of all root crops can be drilled satisfactorily with the "cup and cog" type of corn drill which can be adjusted to a required seeding rate. Carrot seed, being very small and light, is less easy to drill and is often sown mixed with dry earth, sand or wood ashes to secure a thin, even seeding. This crop is not thinned under field conditions.

Seeding rates per acre are used as follows: Carrots, 5 to 6 lb., beetroot 4 to 6 lb., turnips and swedes 2 to 3 lb., parsnips 6 to 8 lb.

Row spacings are usually 15 to 18 inches for carrots, 12 inches for beetroot, 15 to 18 inches for turnips and swedes, and 15 inches for parsnips, though the spacings used on individual farms depend largely on the available cultivating implements.

The seed of beetroot should be sown about 1½ inches deep, but that of

other crops only about ½-inch, and not deeper than ¾-inch. Main crop carrots are not thinned (if the seeding rate is correct the crop will thin itself effectively) but beetroot, turnips, swedes and parsnips should be singled appropriately—normally 6 inches for long beetroot and 3 to 4 inches for round type; 4 to 6 inches for bunched turnips; 8 to 9 inches for topped turnips and swedes, and 6 to 8 inches for parsnips. Any thinning of carrots is apt to bring on attacks of carrot fly if the pest should be prevalent.

Crop cultivations should begin as soon as the rows of seedlings are clearly visible as it is important to control weeds. This work is done either by hand or rowcrop machinery. Some hand work is usually necessary, for few machines can clear the weeds from these crops completely.

Lifting and Storage.—Crops of carrots are either lifted by hand or ploughed out by machinery, but in order to avoid damage, which results in bleeding and loss of quality, crops of beetroot are usually lifted by hand, though sugar beet lifters can be used, with care, for this work. Turnips are similarly lifted for storage, but swedes and parsnips are usually left in the ground until required, small supplies being lifted and stored temporarily to provide against severe weather. Carrots, beetroot and turnips are damaged by frost and should be lifted and stored before severe weather is expected, usually, at the latest, by the end of November.

The storage of root crops requires very careful attention if they are to keep well through the winter. Carrots require very cool storage (a temperature between 34° F. and 38° F. provides the best conditions), and so are best stored in small, narrow clamps in the open field covered with several inches of soil, straw not being necessary, though some growers, mostly in the north, use a thin layer before the soil is put on. Beetroots are very susceptible to frost injury, and though they may be stored in the open are best in larger clamps, like those of mangolds or potatoes, with some straw over the roots before the soil is put on. For safety the clamps should not be placed in an exposed frosty situation, for if frozen through or severely chilled there is a risk of loss occurring. Ventilation openings into the clamp should be provided at intervals on the ridge of the clamp but should be covered with straw during frosty weather. Turnips are clamped like beetroot, but rather smaller clamps should be used.

Marketing.—Maincrop carrots are marketed both washed and unwashed, the former being preferred on the markets. Specially constructed carrot washers are available, but many growers have designed their own types to meet local conditions and water supply. Bags, holding 56 lb. are usually used for marketing, but boxes and crates are also used for marketing attractive samples of washed carrots. Carrots are not usually graded, though the smalls are taken out and marketed separately or fed to stock.

Beetroots, which must at all times be carefully handled, are not washed for market, but are usually graded into two sizes, all damaged roots being

removed. Boxes and crates are the usual market packages for this root crop; bags should not be used.

Topped turnips and swedes, closely trimmed but not washed as a rule, are usually marketed in half-bags (56 lb.) or boxes of about one bushel. A similar method is used for marketing parsnips which should be graded in two sizes but not washed.

VARIETIES

Carrots.—Main-crop, stumprooted type: Chantenay, Blatchford's Early Model, intermediate type: James's Scarlet Intermediate; long type: St. Valery.

Beetroot.—Long type: Cheltenham Green Top; intermediate type: Cobham Early, Covent Garden Red, Blood Red, Nutting's Dark Red; round type: Model Red Globe, Detroit Red Globe, Empire Globe, Crimson King.

Turnips.—Marble Green Top and Green Top Stone are good varieties of white turnips for storage.

Swedes.—Most agricultural varieties are suitable for market.

Parsnips.—Hollow Crown and Offenham are good types for market.

CELERY

Soils.—The three types of land on which celery is mainly grown are represented by the alluviums, including the "Warps" of the Isle of Axholme, the black peaty Fen soils of Cambridgeshire and Norfolk, and the black "Moss" lands of South Lancashire. The three main requirements of a good celery soil are:

1. It must be deep and easily worked.
2. It must contain a high proportion of organic matter.
3. The water table must be high enough to allow the plants to obtain water throughout the growing season.

Rotation.—Although, when intensively cultivated, as by smallholders, celery is frequently grown in successive years on the same land, the best crops are grown on land coming under rotational cropping. Therefore it is a crop suited to arable farming.

On the farms celery has a definite place in a long rotation, such as: Celery, Potatoes, Corn, Seeds, Roots. After celery the land is in good condition for potatoes as it contains residual manure and has been deeply worked. Cereal crops should not follow celery as the land would be too loose and too well supplied with nitrogen. Seeds and roots are grown to supply food-stuffs for the farm, but both these crops, or roots only, are sometimes omitted owing to the higher direct returns obtainable from celery and potatoes.

Manuring.—Applications of farmyard manure are important for the production of good crops of celery. On an average alluvial soil, 25-30 tons per acre are given, but this quantity may be reduced on rich peaty soils well supplied with organic matter. The dung is best used when well rotted; if obtained in the autumn it is stacked to rot down during the winter. Wastage is lessened if the heaps are covered with soil.

When the land is ploughed in the spring, the rotted manure is spread from carts down the furrows where the celery rows will go and is distributed evenly. Warp land is usually manured in March, the manure being immediately covered with soil, but black land may not be manured and covered until May. The use of a complete fertiliser, high in potash, is very beneficial for celery. This may be applied down the rows on the top of the farmyard manure before covering in. A top-dressing of a nitrogenous fertiliser is often given in July.

Cultivation.—The preparation of land for celery is dependent on the previous crop. Stubble land is ploughed and left rough during the winter until early spring. Potato land is scuffled or disced and left rough for the winter. The land is then scuffled and ploughed again, the alluvial land early and the black land later. The digger type of plough is used and is taken twice down each furrow to form a trench, into which the manure is forked. The rows are split in and the land left until the plants are ready to set.

Planting in the Field.—The plants are either raised on the farm or bought in from plant contractors. If raised on the farm, frames or a glasshouse are required in which to sow the seed, and labour is also required for pricking out the seedlings in beds. The seed is sown in warm frames or a glasshouse in January and February and in cold frames towards the end of February and in March. One ounce of seed should produce 24,000 plants. Clean seed should always be used.

The plants are transplanted when about 5 inches high, generally during June. The plants are lifted by a spade, counted into hundreds and then packed into potato-sprouting trays (each tray holding 4,000 plants) and taken to the fields for planting. Large quantities of plants are raised by specialist growers in the Isle of Axholme and Peterborough districts; it has been estimated that 8,000,000 are now sent away annually. These plants are mostly grown on contract. It is advisable to enter into contracts for celery plants as the supply normally available is limited.

To ensure a good "take" showery weather is desirable when planting is taking place.

Prior to planting the rows are harrowed down and raked to a fine tilth. Roughly 20,000 plants will be required per acre at the normal spacing of 4½ inches in rows 5 to 5½ feet apart. No inter-cropping is practised, the celery occupying the whole of the land.

Planting is done by hand and by mechanical transplanter. Methods of hand planting vary according to the district.

Spraying.—Spraying to control leaf spot or "blight" should be a routine operation, both when the plants are in the bed and in the field. Home-made Bordeaux Mixture has been proved by experiment to be the most effective and economical spray. Bordeaux Mixture is made in the usual manner, but hydrated lime is now generally substituted for quicklime as it is easier to handle. The spray is applied by means of various

types of machines, the aim in spraying being to make a fine mist which will form a film on the leaves of the celery so that the fungus cannot become established. As the appearance of the disease is normally associated with damp weather, sprays are immediately applied when the conditions appear to be favouring an outbreak. The number of sprayings required in a season will vary. In some years three are sufficient, in others more may be necessary. Dry spraying, i.e. dusting with powdered fungicides, is also favoured in some districts and is said to give a satisfactory control of leaf spot.

Cultivation in the Field.—Throughout the early summer months the celery crops are horse or tractor cultivated to keep the land loose and clean. Specially shaped hoes are used. Hand-weeding and hoeing round the young plants may also be necessary. This work goes on until the work of earthing up begins.

Earthing Up or Blanching.—The earth used for blanching the celery is gradually banked up round the plants. Methods vary from district to district, and various types of celery moulding implements are in use. The following are examples of methods used in some districts.

(1) The first moulding furrow, when the plants are about 9 inches high, is made by pushing the soil towards the plants with a digger plough. The second furrow is thrown up when the plants are about 12 to 15 inches high. To ensure that sufficient loose soil is available the land is scuffled deeply between the rows. This moulded soil is then pushed close up to the plants with a special "pusher" (made of a wooden board nailed to a handle) the object being to pack the stems closely together and to keep out the light, care being taken not to let earth into the heart of the plant, as this may induce rotting.

After further growth the third or banking furrow is thrown up. The actual time of banking depends on the time when the crop is to be marketed. Early crops are banked shortly after the third furrow, while work on later winter crops may be deferred.

The middles of each row are first scuffled to provide the soil, and the plough with a special breast throws up the furrow. The soil is then pushed up to the plants as before, and tightly packed up to them with a spade. This is known as "shelfing."

The final "topping" of the celery is done about a week after the operation of shelfing. It consists of packing the soil right up to the plants, so that only the green tops show. This work is done with a spade and is generally let out as piece-work.

(2) In the South Lancashire district a plough (either a special celery plough or an ordinary plough fitted with boards), is used once or twice, followed by two lifts with the spade. In this district, wherever the "Moss" consists of firm peat, an implement called a "nicker" is used after ploughing. This is generally made by attaching three "knives" to an old scarifier so that one knife is in a central position and two at the sides. When this is

drawn down between the rows the moss is so cut to leave a spade lift ready for each row. Where the "Moss" is softer, a small plough-attachment is used with a cultivator to throw up a small ridge at the base of the row. This loosened soil is then readily thrown up with a spade.

(3) On the Preston-Halsall "Mosses" the plough is employed twice; first an ordinary horse-plough is used, and then a plough with boards attached. Two "lifts" with spades are also given. A "pusher" board, similar to that employed in the Lincolnshire district, is used to firm the soil round the base of the celery.

Top Dressing.—When about 15 inches high, after the "second furrow" is made, the plants benefit from a nitrogenous top dressing. It must not, however, be given in excess or the celery will become soft. Sulphate of ammonia and nitrate of soda are used for this purpose, and are usually applied at a rate not exceeding a total of 3 cwt. per acre in three dressings sprinkled down the rows. Smaller dressings are applied on Fen soils.

Lifting the Crop.—The time of marketing the crop depends on many factors, including variety and soil. The white varieties, which blanch earlier, especially on sandy and peaty soils, may be ready to lift by the end of August. It is a mistake to try to catch the early market by lifting the crop while still too green, for it is difficult to dispose of badly blanched celery. When the outer leaf stems are blanched for a third of their length the crop can safely be lifted.

When lifting celery the bank is first ploughed away on one side, and a man follows with a spade digging out the plants and severing the roots. He may also shake the plants and remove injured leaves, or another man, the "trimmer" follows to do this. The tier then bundles up the "heads" in dozens for market.

The usual practice is to bundle a dozen "heads" tied at the bottom with a band and at the top with willow. Four good "heads" are usually placed for the bottom, four or five smaller ones for the middle and four good ones for the top, though it is considered poor practice to put small heads in the centre. If not bundled the heads are made into "fans" so that all heads are exposed to view. Most progressive growers have now adopted grading so that the bundles and "fans" are of a uniform character throughout.

Marketing.—Generally the bunched celery is loaded loose on to lorries or railway wagons and sent direct to market. If more is lifted than can be despatched immediately it may be "pitted" for a few days during the mild weather early in the season. Pits are made down the rows and the celery is packed in to stand upright in the pits, three bundles abreast.

Washing and Wrapping.—Modern methods of washing and wrapping celery on the farm have been adopted widely and many growers have installed modern machinery specially devised for rapid handling. The heads are carefully trimmed, washed clean and, after wrapping in suitable damp-proof paper or cellophane, are packed in wooden crates

according to their respective grades. As a rule the crates contain 12, 18 or 24 heads. The availability of crate wood, paper, etc., affects this type of marketing.

Varieties of Celery.—Varieties of celery fall into red, pink and white groups or types. There is considerable variation in commercial strains. Two types of leaf are met with, so that varieties may fall into the Clayworth (sparse leaves, narrow and sharply serrated, which give the impression of "small tops") or the large top, Manchester type. These types are again subdivided into tall, intermediate and dwarf, and still further into White and Pink. While the catalogues of seed merchants who cater for growers are a reliable guide, some of the best known commercial varieties are as follows:

White Group.—The white varieties are the earliest and at the same time most susceptible to damage by frost, and in consequence are most suitable for black soils to supply the early market.

Dwarf:	White Gem or Dwarf White (early)
	Wareing's Dwarf White (early)
Intermediate:	Sandringham (early)
	Clucas's Market White (maincrop)
Tall:	Solid White (maincrop)
	Manchester White (maincrop)
	Blundell's White (maincrop)

In the Axholme area of North Lincolnshire the following have proved to be good white varieties:

Bibby's Defiance (short, thick sticks)
Blundell's White
G. F. Brown's White (long, solid sticks)
Clucas's Market White

Wareing's Dwarf White has yielded small firm hearts very suitable for canning.

Pink and Red Groups.—Some pink varieties show but little coloration; others are deeply coloured, such as Clayworth Prize Pink and McHattie's Giant Red. Others also suitable for commercial culture are less deeply coloured.

Unlike those of the white group the pink varieties are resistant to frost and improve in quality under frosty conditions. Some of the best strains grown are:

Clayworth Prize Pink, Dick's Champion Pink, Clucas's Perfection Pink, Ball's Pink, Cookson's Pink, Gabbot's Pink (seen only in Lancs.).

All except the first-named are of the Manchester type and reliable for the maincrops. All give a very big plant with considerable top and large leaves, bluntly serrated.

Clayworth Pink is one of the most popular pink celeries grown, and many local strains are grown in both Axholme and South Lincolnshire. In general the Clayworth is a late celery.

Other good pink varieties are A1, Leicester Red, Dawson's Pink and Clucas's Prize Pink. Prize Dwarf Red is a good dwarf variety.

The self-blanching celeries are distinct types requiring a different system of cultivation than the ordinary celeries. Varieties have been grown successfully in this country under market-garden conditions. They have either green or golden leaves and the plants are short and stocky and mature early. The Doré celery of the French is included in this group.

PEAS FOR MARKET, CANNING AND DRYING

Economics of the Crop.—For several reasons peas are a good type of crop for the farm, for they fit well into farming rotations, and can be dealt with by the normal farm machinery. Green peas for the market, however, need casual labour for picking, and this crop should not be grown unless there is a reliable supply of pickers available. It has long been recognised that peas come next to potatoes in terms of total cash value amongst the vegetable crops grown in this country. For the year 1939 a total acreage of 88,600 was recorded of which 28,000 acres were for canning and drying. During the war years, peas were of front rank importance, and special efforts were made to increase the acreage, especially of crops for drying and canning. As a result of planned production the pea crop was increased by no less than 428 per cent. In 1945, 210,891 acres of peas were grown, of which 63,090 acres were for picking green, 132,113 acres for drying and 15,688 acres for canning.

Climatic Conditions.—Peas are greatly influenced by the weather. Although the seed germinates at a relatively low temperature there is a risk of it rotting in the soil if the weather be cold and wet after sowing, especially with wrinkle-seeded varieties. Dressing the seed with organo-mercurials not only checks disease but ensures a stronger and more even germination. Once the crop is up it grows best under conditions of moderate temperature and bright sunny atmosphere, with occasional showers to keep the soil cool and moist. Experienced market growers say that it is the weather of May that makes or mars the crop, for if it should become hot and dry the plants are checked and seldom recover vigour. The crop does best when it grows slowly but steadily, and for this reason early-planted crops are always the most successful. When the plants are in full growth and in blossom, a spell of hot weather may not only have an adverse effect on pod setting and development, but may bring attacks of aphides and thrips, especially on later sown crops.

GREEN PEAS FOR MARKET

Soils.—For maincrop peas, deep loamy soils, for example, clay-loams, silt-loams and brick-earths which are well-drained, are considered best. Soil conditions, however, are linked with season of cropping and variety. Early crops may be taken from lighter soils that would not carry maincrops successfully. Very heavy clay loams should not be used unless well-drained,

for in a wet season they may become waterlogged and peas will not thrive on wet land.

Peas are sensitive to soil conditions of a chemical as well as physical nature, for while succeeding under marked alkaline conditions they will not thrive in a soil of high acidity. The pea, being a leguminous plant, establishes a symbiotic association with nitrogen-fixing bacteria in the soil, and this association develops with greater facility when the soil conditions are favourable to the growth of the plant. Although the use of inoculated seed is advised in the U.S.A. it is unnecessary and rarely used in Britain.

As regards the physical condition of the soil, there seems little doubt that peas need a firm seed-bed, with a good surface tilth; they do well on soils possessing a granular structure, formed through the biological agencies of root action and organic matter. This is probably one of the reasons why peas do well on ploughed-out leys or old grass land. The crop is not liable to injury by wireworm.

Place in Rotation.—In pea-growing districts the view is held that the crop should not come twice on the same land within five or six years; some growers say eight years. It therefore fits in with arable farming rotations and in this respect is accommodating. In the ordinary four-course rotation peas can alternate with beans or clover on the leguminous shift, and so need not come on to the land at all frequently. It is customary to crop peas after wheat in ordinary arable rotations, but, as has been demonstrated by the Norfolk Experimental Farm at Sprowston, wheat can *follow* peas with success, which may mean peas on a ploughed-out ley. Where potatoes are grown in a five-course rotation peas may follow that crop, or they may follow roots or a Brassica crop—the point being that the crop does well on manurial residues such as are commonly available after these crops. On heavier types of land particularly, peas are one of the best crops for newly-broken old pasture.

Manuring.—Being fundamentally a seed crop, in manuring peas the nitrogen factor should be watched carefully, otherwise much unfruitful haulm is grown. The crop, of course, uses some nitrogen, but unless the land is very poor it is best supplied in the form of fertiliser and not as farmyard manure. The important fertility factors are phosphate and potash, the ratio of which should always be adjusted to suit the land. In general a 1 : 2 : 1½ nutrient ratio is suitable for the pea crop. Both superphosphate and basic slag may be used on peas, the latter giving better results on heavier types of land, as Oldershaw found at Saxmundham. Muriate of potash is a suitable source of potash for the pea crop.

For peas there is no doubt that phosphate is of prime importance and potash less so. Nitrogen is required only when the land is in poor heart. In general, peas on sandy-loam soils should receive approximately 30 lb. of nitrogen, 50 to 60 lb. of phosphoric acid and 40 lb. of potash. On silt and clay loams they should receive approximately 20 lb. of nitrogen, 50 to 60 lb. of phosphoric acid and 30 lb. of potash. While the phosphate and

potash should go into the seed-bed well in advance of seeding, the nitrogen may often do most good if it goes on as a top dressing during growth. For market peas a top dressing of nitro-chalk is often of very material value to assist podding and hasten the picking date. Experimental work has shown that nitro-chalk is a steadier and more lasting nitrogenous fertiliser than either nitrate of soda or sulphate of ammonia. Satisfactory results have also followed the use of Chilean potash-nitrate. Good crops of peas are often grown on loams in good condition with a fertiliser dressing of 2 to 3 cwt. of superphosphate only.

Cultivation.—The land is best ploughed in early winter. On stronger loams, especially, the weathering effect of winter conditions will be beneficial. During periods of drying weather in February, or later, according to the time of sowing, tillage with drags and harrows will get the land into a seed-bed condition. Care must be taken with seed-bed tillage, for peas prefer a crumbly tilth. A very fine tilth on silty loam will tend to form a crust after heavy rain. Unless the soil lifts after sowing, the use of the roller is seldom called for. Two factors are recognised as inimical to good germination. First: soil which is too fine so that it runs together to form a crust which hampers the seedlings in early stages of growth. Second: deep drilling, which may result from looseness of soil. All cultivations prior to sowing have, therefore, a definite aim in view, to prepare a seed-bed which is firm and of good tilth but reasonably cloddy on the surface.

Sowing.—Although some early crops are sown in the autumn in favourable districts the bulk of the crops are sown in early spring, from about mid-February onwards.

It is now common practice to sow from 2½ to 4 bushels of seed per acre, depending on row widths which in turn depend on the type and variety of pea. Early crops may be sown more thickly to make up for losses. The seed is commonly sown with an ordinary grain drill. The Suffolk twelve-coulter cup drill makes a good pea drill, and can sow at 7½ inches, 15 inches, or 22½ inches with no adjustment beyond removal of the unwanted coulters. The use of combine drilling for peas is not considered advisable.

Little is gained by having market peas close in the rows. Rows should not be closer than 12 inches, and 15 inches is a good row width for many varieties of moderate height. Wide row spacing, even up to 22½ inches, allows for adequate cultivation for clearing weeds and gives the plants more room to develop. Good average row widths are 15 inches, 18 inches, and 22½ inches, according to variety. At 15 inches, 2½ to 3 bushels of seed can be drilled to give a satisfactory plant; from 2 to 2½ bushels will be sufficient for wider spacings. When tall varieties are grown, as little as 1½ bushels can be used at 24 inches to secure a satisfactory plant, but it is as well to allow 2 bushels.

Deep sowing should be avoided, for it often results in loss (through rotting) and a slow germination which gives poor stands. A depth of 1 inch

is sufficient in moist heavy loams and up to $1\frac{1}{2}$ inches in drier types of soil. A depth greater than this is not necessary. If the seed-bed is firm and not puffy, deep sowing is easier to avoid.

Crop Cultivation.—Some soils tend to lift under the influence of weather. To remedy this the land is rolled with a light roller either just before the plants come through or about two weeks after. Rolling is by no means necessary and should be done only when soil conditions call for it.

Peas become a weedy crop and one of the advantages of wider rows is that row-crop cultivation can be done to control weeds before the plants become high enough to interfere. Market peas should be given one or two shallow cultivations, which may be carried out with row-crop machinery if the rows are not less than 15 inches apart.

As peas dislike a crusty surface during the early periods of growth and weeds come through quickly, a harrowing of seedling peas is often given when about 3 inches high. This may seem hazardous, but any apparent damage to the crop is repaid by better subsequent growth and the suppression of seedling weeds. Special light pea harrows are used.

When cultivations are finished the crop needs little further attention until picking time. If a nitrogenous top dressing is to be applied during growth it must be put on before the plants go over. If docks, thistles and other perennial weeds appear they should be pulled or spudded out.

Picking the Crop.—This crop has to be picked by hand, and any extensive acreage calls for many pickers, often running into hundreds, if the crop is to be gathered before it spoils. In hot weather the crop quickly becomes "corny" or starchy, and loses the best market quality so essential as a selling factor. A crop may spoil within a week.

Three types of pickers are used—locals, gipsies and townspeople. Each have their own peculiarities and need appropriate handling. There is little to choose between them. Gipsies are very good at pea picking, for they work in big family groups and are keen on earning as much money as possible while the season lasts. Townspeople, other than experienced hands, are apt to be troublesome. Unless pressed, the grower should always engage experienced pea pickers for they know what to do, get on with the job, and require little supervision.

The universal practice is to clear the crop at one picking, the pickers pulling the haulm and stripping it of all pods. This does not make for a good sample because some of the pods will have passed prime condition while others will not have filled out. Few growers, however, do any grading of field crops, but some give instructions for all "flats" (empty pods) to be kept out of the bags.

The picking is done on the basis of a fixed price per bag of 40 lb. The price varies and has been known to be as low as 7*d.* and as high as 2*s.* 6*d.* Before the war it was usual to pay about 10*d.* or 1*s.*, but in recent years higher prices have had to be paid to get crops picked.

Good crops may be expected to run to over 200 bags per acre, hence it is easy to calculate the number of pickers required to handle a crop with reasonable speed, for example, eight good pickers per acre for a three-day picking. The bags should be filled and weighed and covered with a sheet until moved into a cool shed to await transport.

No time should be lost in getting the peas to market. Freshness is not only an important selling factor but also a factor affecting edible quality because of the changes in the sugar-starch ration which take place after picking. The latter in turn are affected by temperature, so that pre-cooling of picked peas before transport, and transport after sundown, are important points in handling the crop.

GREEN PEAS FOR CANNING

The canning of peas has grown in recent years to be a business of considerable proportions. In addition to the fresh green peas canned during the summer months, dried peas are also used by the canners for processing during the winter months. Green peas for canning are usually a contract crop, for the factories prefer to make arrangements with farmers in order to secure an extended and well-planned canning run. They also have their own field men who keep in touch with the farmer so that the factory is kept closely informed concerning the progress of the crops. The farmer in turn is advised on cultural details and instructed as to the correct time for harvesting.

Contracts with the farmers tend to vary. With one type of contract the farmer undertakes to do all tillages, sow and cut the crop, the canning concern supplying the seed and making its own arrangements for transporting the crop on the vine to the factory. With another type of contract the farmer undertakes to grow and deliver the crop, vining it either at the factory or at a vining centre, or perhaps on the farm. Payment is paid on the basis of actual weight of shelled peas delivered. The farmer may invest in the viners or they may be hired at an agreed yearly rental.

Centres of Production.—The important centres for pea canning are the Wisbech district of Cambridgeshire, the Boston and Spalding districts of Lincolnshire and the Evesham and Pershore districts of Worcestershire, districts which provide the types of soil favoured—cool silt or clay loams which are in good condition as a result of constant tillage and manuring for such crops as potatoes, sugar beet, celery, etc.

Varieties Grown.—The peas most suitable for canning are those which retain their shape without cracking, keep a fresh green colour after processing and, above all, possess quality; that is, a sweet green-pea flavour with a minimum of starchy or mealy taste. From the field point of view the best varieties are those with a good constitution, free from rogues and which mature their crops evenly. Most of the good canning peas are in the wrinkle-seeded class, for although they do not mature so

uniformly as those of the round-seeded class, they are sweeter and better flavoured generally.

Land Preparation.—The land is prepared on lines similar to those for market peas. Canning peas should go on clean land, for fouling weeds such as docks, thistles and goosefoot, if cut with the crop, cause trouble with the viners.

Sowing.—Normally, canning peas are sown rather later than the earliest market peas, beginning as a rule about the middle of March and running on for successive crops into early May. Two or three batches of the same variety of earlier types, such as Surprise and Thomas Laxton, are often sown, especially in April, a good month for canning peas. The Lincoln, Canner's Perfection and Charles I are also useful for sowing in successive batches; they will come in regularly on average soils of fair moisture content.

The seed is sown with a grain drill, and it is customary to have the rows fairly close so that the crop is kept up with its own support and is easier to mow. Many crops are sown at 7½ inches, with the full set of counters on the grain drill; stocky varieties like Thomas Laxton, Onward and The Lincoln should be 15 inches, if not 18 inches apart, to give their best podding performance. Seeding at the rate of 3 bushels per acre should give a satisfactory stand of plants at 7½ inches—say, up to twenty plants per yard run of row and rather more at wider spacings. The rate of seeding affects both period of maturing and yield per acre. As a rule 3 bushels per acre should be drilled.

Cultivation of the Crop.—The crops are cleaned and cultivated on lines similar to other crops of peas. Provided the land is fairly clean, not more than two row-crop cultivations are needed as a rule.

Harvesting.—Canning peas are usually ready for harvesting from about the end of June onwards, depending on the season. Earlier sown crops may take up to twelve weeks from sowing to maturity, but later sown crops of the same variety take rather less, e.g. crops of Surprise sown in April will mature in from eight to nine weeks.

The modern vining machine is now standard equipment for separating the peas from the pods and vines. It shells the green peas straight from the vines as they are fed into it from a conveyor, delivering the peas into trays ready for processing and the threshed vines on to another conveyor to be returned to the farm.

The crop is cut with mowing machines which are sometimes fitted with pick-up devices on the cutter bar. The farmer usually mows as much of the crop in the early part of the morning or in late afternoon as can be trucked to the factory the same day. It is risky to leave vines lying after cutting; they should be taken to the viner while still fresh. The vines are not heaped or thrown together as there is then a danger of heating and spoiling. Freshness is the keynote of handling canning peas.

The crop yields of canning peas tend to vary rather considerably.

At Wye they have averaged 26 cwt. per acre over a number of years. Alaska, under average conditions and with no special manurial treatment, can be expected to yield at least 25 cwt. of threshed peas per acre, Surprise up to 30 cwt., Onward and The Lincoln up to 30 cwt., but of course heavier yields will be recorded. High yields of canning peas may easily cost too much to produce in relation to the financial returns. (In other words moderate crops pay best.)

Pea Vine Disposal.—The threshed pea vines are a valuable stock feed whether made into silage, fed green, or as dry pea straw. At Wye, Hervison found that the vines gave a silage showing a protein equivalent of 4·7 and a starch equivalent of 15 per cent. Average yields of 60 to 70 tons of silage were obtained from 30 acres. Analyses of pea straw samples have shown that where the amount is too small to make into silage it is well worth the trouble of spreading and drying. Protein contents range from 9½ to 10½ per cent. Lastly, if not required for feed purposes green pea vines make excellent compost.

PEAS FOR DRYING

The production of edible dried peas is an enterprise of long standing and owes its inception to the initiative of a few firms which foresaw its possibilities many years ago when the fine hardy blue pea, Harrison's Glory, was introduced. There are two distinct forms of it, one with long and the other with short straw. The short-straw form is considered the best to grow on the better types of land.

Peas for drying are often grown on contract either for the canning factories or for one of the packet pea firms which specialise in marketing the product. Even if not on contract, crops should preferably be grown on a basis of some agreement with a marketing organisation, for it may be difficult to market "free lance" crops. The firms engaged in the trade prefer to plan ahead, and to have some idea of the quantities they are likely to handle after harvest.

Location of Crop.—This pea crop is now fairly widespread, being grown in nearly all the eastern and east-midland counties as well as in Kent, Sussex, and East Riding of Yorkshire. The location of this crop is largely affected by climate, for good late-summer weather conditions are essential to a satisfactory harvesting of the peas in a good condition. It might be said that the best corn districts of the country are generally suitable for peas.

Land for the Crop.—There is no doubt that while these peas succeed on a wide range of soils, the strong loams are the best, provided they are well drained and not short of lime. If there is any doubt about the lime status of the land, a ton of carbonate of lime per acre (ground chalk is an excellent form) should be applied. Oldershaw has obtained good effects from dressings of chalk up to 5 tons per acre on an acid soil at Tunstall (pH 5·8) on a pea crop grown five years later. The effect of

this chalking was to raise the crop from 8 bushels to 31 bushels per acre.

As regards a fertiliser treatment, a moderate amount of a complete fertiliser is generally regarded as a profitable investment, say up to 500 lb. per acre of a mixture containing approximately 4 per cent. nitrogen, 8 to 10 per cent. of phosphoric acid, and from 6 to 8 per cent. of potash. Such a 4 : 8 : 6 fertiliser provides the 1 : 2 : 1½ fertilising ratio which seems suitable for peas.

Sowing.—When sowing this pea crop regard must be paid both to contributed soil moisture and the best harvest period. The latter can be said to coincide with the corn harvest—mid-July to mid-August. As Harrison's Glory takes from about twelve to fourteen weeks to reach cutting condition, mid-March is early enough to sow, and from then to mid-April can be regarded as the optimum sowing period. Row widths of 15 inches and 21 inches are most suitable, using seed rates of 4 and 3 bushels per acre respectively.

Harvesting the Crop.—When threshed, the peas should be fairly hard, but not brittle, should retain the desirable bluish-green colour, and should not be sun-bleached. These quality factors depend entirely on the method of harvesting the crop. It is possible, under some conditions, to cut the crop in the ordinary way with a mower, leave it in windrows to dry for ten days or so, and then thresh it with a combine harvester which picks up the swathes as it goes along.

The old method of harvesting, which has served this country a great many years, is to cut the crop with a mower fitted with a lifting device and sometimes with an additional attachment to slide the swathes aside out of the way. The swathes are frequently turned, then swept into cocks and finally picked up and stacked until threshing time. In very wet weather the peas may require turning every day and in very bright weather turning is also necessary to prevent bleaching. There is a good deal to be said for this method, for peas are better for stacking before threshing, a brighter-coloured and certainly a drier sample being obtained.

In districts where the weather at harvesting time is uncertain, more use could be made of the tripod or the four-pole method of drying this crop. A better quality of grain is obtained by tripod drying, and many growers are now using them for the reason given above. For average crops from fifteen to twenty tripods per acre are needed, depending on length of straw. It is important that the crop should be in correct condition three to four days after cutting. It should be built up systematically on the tripods or four-poles so that rain cannot enter; each pile must be adequately ventilated. If these precautions are taken there is no urgency to move the crop into the stack; it can even be threshed direct off the tripods. With tripoding, too, the straw is dried in better condition for feeding purposes and a larger proportion retains good nutritional value.

Threshing the Crop.—Compared with some crops, peas are easily threshed out with the ordinary grain thresher, provided the machine is

correctly set and the drum speed adjusted. The latter should be as slow as the machine will take the haulm satisfactorily, but not higher than 600 r.p.m. Drum speed on most standard machines can be reduced by altering the driving pulleys; thus only the drum is slowed without affecting the air blast or the riddles, which otherwise would result in a rubbishy sample.

When using combine harvesters a cause of unsatisfactory threshing may be the overloading of the machine by having the swathes too large. It is better for the machine to work along swathes on the light side rather than the heavy.

No matter what care is taken some rubbish will get through into the sacks, and to attract the buyer it is worth while running the peas through a dresser before offering the crop for sale. If it be a contract crop the position is different, for usually the firm that placed the contract will clean the crop to its requirements.

Yields vary considerably. They commonly range from 15 to 20 cwt. per acre.

RECOMMENDED VARIETIES

Green Peas for Market:

EARLIES: Early Bird (Blue Bird), The Clucas, Foremost, Pilot, British Lion, Laxton's Superb, Thomas Laxton, Gradus.

MAIN CROPS: Onward, Senator, Dwarf Defiance, Duplex, Alderman, Sharpe's Standard, Admiral Beatty, Clucas's Ormskirkian.

Green Peas for Canning:

EARLIES: Alaska, Gregory's Surprise, Thomas Laxton, Kelveden Wonder, Witham Wonder.

MAINCROPS: The Lincoln, Onward, Canner's Perfection, Charles 1st.

Peas for Drying.—Harrison's Glory, Lincoln Blue (syn. Small Blues).

CHAPTER 6

FRUIT GROWING ON THE FARM

By Eric W. Hobbis

Kent, our premier fruit-growing county, has demonstrated the practicability of growing both tree and bush fruits along commercial lines as part of the general activities of the larger farm, and similar mixed general and fruit farms are also of common occurrence in the West Midlands.

The grass orchards of the south-west were originally planted mainly to supply apples for the cider press, with a small proportion of fruits for market purposes, and in these the standard of growing has been generally on a low level. Many acres of these orchards were cleared during the recent World War and the land put to other uses for farm crops. With the present-day demand for high-quality market fruits it seems unlikely that these farm orchards of the old type will ever be suitable for the production of market sorts. Cider-fruit growing, however, presents better prospects, provided the management is good.

The most suitable fruits for mixed farms are apples, pears, cherries, plums, blackcurrants, raspberries and strawberries. The tree fruits are all suitable for arable or grass conditions, but blackcurrants, raspberries and strawberries require a high standard of arable cultivation.

All these fruits are already grown in quantity by specialist fruit growers, who have learned by experience that it is only fruit of high quality, well grown, carefully harvested, well graded and attractively packed for market, that shows a profit. Fruit growing, to be successful, must be a specialised department of the farm; it has little prospect of success in a secondary role on the general farm.

Fruit crops, with the exception of strawberries, are mostly long-termed and therefore outside any ordinary scheme of rotation. Special machinery for spraying and cultivation must be provided, and marketing also brings special problems of equipment, accommodation and packing. Harvesting, being seasonal and most of the crops highly perishable, necessitates a local supply of temporary labour and this work may compete seriously with the cultivation and harvesting of agricultural crops. For example, haymaking usually coincides with strawberry, blackcurrant, raspberry and cherry picking, and cherry harvesting in particular, calls for both male and female labour. Corn harvest extends at least through the first half of the plum season and potato lifting may be simultaneous with the late apple harvest.

The established farmer has an advantage over the newcomer to specialist fruit growing in that his income prior to the trees bearing crops

is provided by other farming activities. As a rough guide, the cost of establishing and bringing into cropping an acre of apples, plums, or cherries has been computed at between £100 and £200.

Soft fruit planting costs are largely accounted for by the purchase of plants, although in the case of raspberries additional expenditure may be necessary for wiring and supports. Establishment costs are lower, too, by reason of the shorter period prior to cropping.

High quality of planting material is of paramount importance in fruit growing, not only to ensure true naming of the varieties grown, but to be certain that the material is free from virus and other diseases. In this connection the Ministry of Agriculture and Fisheries has initiated schemes whereby specially grown nursery stocks, e.g. of strawberries, blackcurrants, raspberries and recently of tree fruits, are granted certificates provided they reach certain prescribed high standards. Official lists of registered growers of certificated nursery stocks are issued annually by the Ministry and the fruit grower should safeguard himself by purchasing only from such sources.

Finally, the point must be emphasised that fruit growing is a long-term policy. With the exception of strawberries (2 to 3 years), all crops are planted with the expectation of a long, profitable life; blackcurrants for 10 years, and apples, pears, cherries, etc., for 50 to 60 years or more. Fruit growing, therefore, can only appeal to owner occupiers or tenants with a long lease (at least 21 years) or to the landlord who is willing to grant facilities to tenants wishing to plant trees and to compensate them if disturbed.

SPECIAL REQUIREMENTS OF FRUITS FOR SITE AND SOIL[1]

Site.—Fruit growing demands a site as free as possible both from the menace of spring (April and May) frosts and shelter from undue exposure to wind. Valley bottoms and sheltered hollows in hilly country are alike unsuitable as being potential "frost pockets."

A general recommendation is to select land of suitable elevation which is high in relation to the general level of the surrounding country. A plateau site with land sloping away from it in two or three directions and with comparatively little high land nearby, will usually provide good conditions.

Soil.—Fruit soils should be of good depth, should have free drainage although retaining moisture in summer, and as a class, loams are usually suitable, but neither apples nor pears require the "rich" soil conditions in the sense usually understood by the farmer.

Cherries in Kent are grown mainly on deep brickearths and these soils have a high reputation for this crop, but in the West Midlands this crop is grown on a wide range of soils. Free drainage is vital to successful growth.

Plums and damsons succeed under the poorer conditions associated with heavier soils, especially where natural lime content contributes to

[1] See Vol. 1, chapter 4, page 152 for discussion of Climate.

good drainage conditions. It was previously thought that plums and cherries require calcareous soils but this has been shown to be incorrect and a high lime content is frequently deleterious and results in chlorosis of the trees.

Blackcurrants and strawberries are grown successfully on light soils and on heavy loams which, naturally, or assisted by cultural methods, afford a free rooting medium and which hold an ample moisture supply in the late spring and early summer months. Raspberries need free rooting conditions and are intolerant of impeded drainage.

GENERAL REQUIREMENTS

Equipment.—The mixed farm will already possess most of the tools and implements needed for the fruits mentioned, although few farm ploughs, for instance, especially if tractor drawn, are low enough, neither can they be offset sufficiently for work beneath tree branches. Ploughs, disc harrows, spring-tined cultivators, horse hoes and tractor-drawn rowcrop tools all find a place in the cultivation of tree and bush fruits. Horse-drawn implements have a specially useful place in the cultivation of raspberries, strawberries and blackcurrants.

Grazing by livestock is only possible with half or full standard trees. The bush apple or pear tree plantation in grass must be mown frequently either with the ordinary hay cutter or by "gang" mower, or the grass may be kept short by folding poultry.

Buildings.—Cover must be provided for seasonal equipment such as ladders, boxes, baskets, etc., in addition to dry housing for implements and tools. Where apples and pears are grown, accommodation will become necessary to house the crops during grading and packing. Where crops are large the provision of a suitable fruit store may be necessary in order to spread the marketing over a period of several months.

TREE FRUITS—GENERAL CULTURAL PRACTICES

Preparation of Land.—As fruit trees are planted with the expectation of a long life, soil preparation before planting should be as complete as possible. Two essentials are satisfactory drainage and freedom from perennial weeds; these should be secured at the beginning, as neither can be satisfactorily accomplished amongst standing trees. Tree planting is usually done under arable conditions and land intended for fruit should be cropped for a few years before planting, to get a clean "face" and a good depth of worked soil. Subsoiling during this period will be beneficial on many soils.

On light soils, deficient in humus, the ploughing in of vegetable crop waste or of green manure crops, will materially assist the conservation of summer moisture during the early years of the plantation, when clean cultivation will be the general rule. Vegetable crops grown preparatory to fruit tree planting can provide a useful guide to certain mineral

deficiencies of the land which can then be remedied before planting takes place. In particular, soils shown to be deficient in potash should be given generous dressings of potash fertilisers prior to planting.

Where grassland is broken up to be planted without any previous cropping, ploughing should be done during the summer to allow of thorough cleaning operations and to enable the turf to be killed and ploughed down to a good depth before winter. Planting can then proceed "on the furrow."

In farm orchards or on hillside plantings where it is desirable to retain a grass surface, the trees can be established satisfactorily in grass, provided each tree station is properly prepared and an area of soil around each tree, of four to six feet diameter, is kept cultivated until the tree becomes established, usually a period of five to six years.

Windbreaks.—Badly-sited windbreaks may do more harm than good, especially when they cross the line of slope and thereby tend to impede the cold air flow of radiation frosts.

Autumn gales do serious damage to fruit, and shelter from prevailing, usually S.W., gales is often of value in preventing the loss of windfall fruit. Trees commonly used have been *Cupressus macrocarpa* (in genial climates), *Thuja*, beech and larch, all of which must be planted at a sufficient distance from the fruit trees to prevent root competition. Tree belts of this kind tend to harbour rabbits and may need special wiring-off for this reason.

Fruit trees however, can provide their own shelter and much wind damage can be prevented within a plantation by planting strong-growing varieties around the outsides. These trees may be planted in lines somewhat closer than the main field planting. They must be kept free from pests and diseases during the course of routine spraying, and pruning should be of a "regulated" character only. Such shelter trees should contribute something to income, and plums, such as Kentish Bush, Blaisdon Red and the Prune Damson are often planted for this purpose. Shelter belt fruit trees should be half-standards or full standards so as to allow of free air flow at ground level, especially when bordering "frost pocket" areas.

Time to Plant.—Planting can take place at any time between October and March when conditions are dry enough to allow of thorough treading and firming of the soil around the roots, without packing or puddling.

Planting.—The essentials of good planting are (1) correct depth (2) ample room for roots (3) firmness. It must be deep enough to cover the upper roots with a few inches of soil and no more; and deep planting must be avoided, as it is a frequent cause of trees dying, especially on heavy land. The graft or bud union must be kept above soil level, otherwise the tree may "scion root," and thus destroy the effect of the rootstock.

If tree stakes have been driven beforehand it is necessary to dig the holes on one side only—the leeward side, when planting in arable land. The subsoil should be broken and a little of the top-soil returned to the hole in which to place the roots.

When planting in grassland the turf should be peeled off from an area some four feet in diameter—around the tree stake if this has been driven—and the top spit dug out. The second spit should then be loosened by forking and the turf placed grass downwards in the hole and chopped into small pieces. A few inches of top soil should then be spread over the turf and the tree planted, the soil covering the roots being treaded frequently and very firmly as it is filled in. A final treading should be given when the top of the hole is reached and the operation finished by covering the surface with a loose layer of top soil.

Staking.—Fruit trees should not be planted and left unsupported. Stakes are best driven before planting, except for short-stemmed bush trees, when it is best to set the stakes at an angle of 45° with the tops headed to windward and to drive them in after the trees are planted. Stakes should be long enough to be driven 18 inches to 24 inches into the soil and to reach within 6 inches of the first branches of the tree. Chestnut makes one of the most lasting stakes, but other woods may be cut on the farm, peeled and creosoted and be very useful substitutes. Old gas piping and engine boiler tubes are also very strong and durable and can be cut to appropriate lengths.

Tying.—Tying material may consist of anything soft and reasonably durable. Hay cord is excellent and will last about twelve months, by which time any type of tie needs inspection and probably loosening to prevent stricture of the tree stem. A strong tie can be made of hosepipe threaded with wire and twisted twice around the tree stem and secured at the back of the stake.

In fixing any kind of tie the correct method is to fix it close to the top of the stake, to tie securely around the stake to prevent slipping, and to have the tie just slack enough around the tree to allow the stem to thicken without injury.

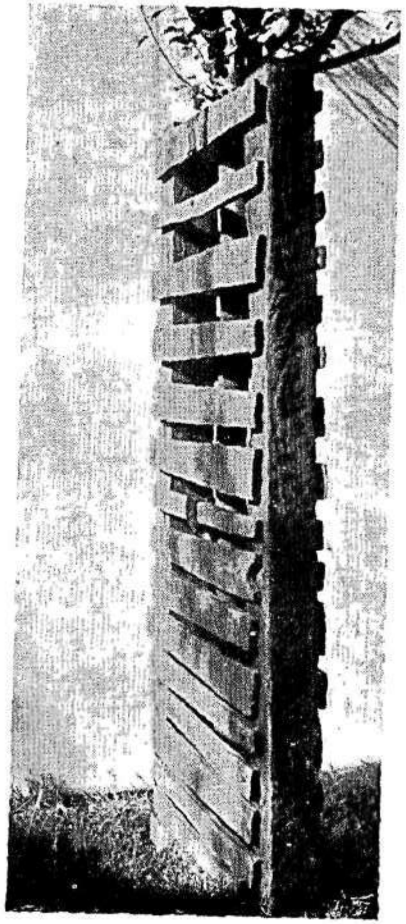
Protection.—Trees in standard orchards which are grazed by livestock need some form of cattle and sheep-proof cage, or "crate," of 16 gauge, 1-inch mesh wire-netting which is reinforced with barbed wire as illustrated in Plate facing this page.

Where no livestock is involved the individual tree cage of wire netting is the best method, with the stem 3 feet or more in height. Short-stemmed bush trees, say, 2 feet 6 inches or less, cannot be effectively protected against rabbits and hares by the cage method and the field surrounds must be wired in. For this purpose 4 feet × 1 inch × 18 gauge netting is suitable, the bottom 6 inches of netting being buried about 3 inches below soil level and bent out at right angles on the outside of the fence.

Tree Station.—Accurate alignment of all the trees in a plantation is important, not only to satisfy the eye, but to prevent damage by machinery set and adjusted to specific working widths.

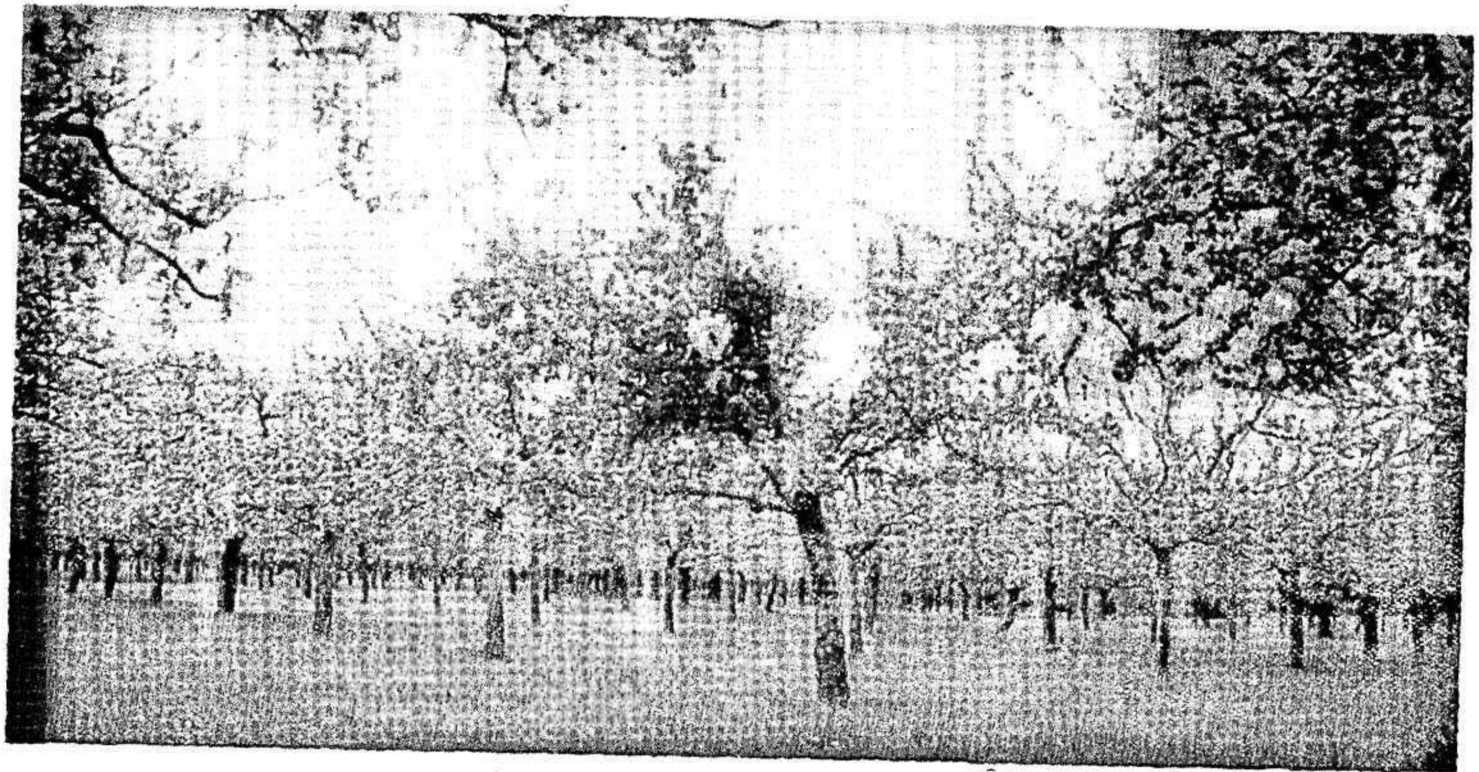
Planting on the square is much the easiest method to employ, and in later years, should the trees become overcrowded and thinning out be

Stock-proof tree guard or "crate" made of 16-gauge wire-netting, reinforced with barbed-wire hoops.



Tree guard and support made of sawn timber posts and odd lengths of wood.

(*Both by permission of Long Ashton Research Station.*)



A 38-year-old orchard of standard apples, Bramley Seedling in the foreground.

(*By permission of Long Ashton Research Station.*)

necessary, the procedure is simple. Quincunx planting, i.e. trees on the square and one in the centre of each square, is a good method provided the squares are large enough to avoid any interference from the centre tree. Such a plant is easily thinned by taking out trees in the centres of the squares.

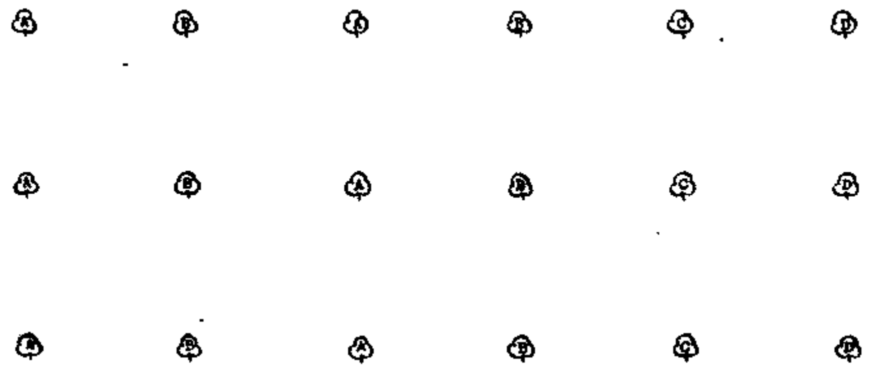


Fig. 5.—The square arrangement of trees.

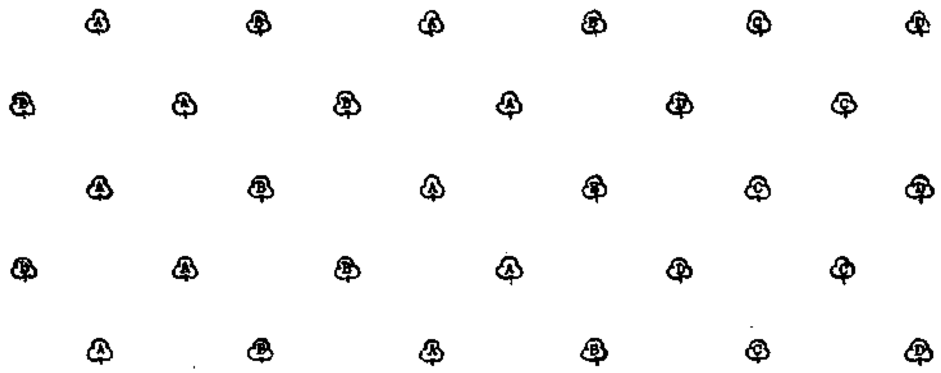


Fig. 6.—The quincunx arrangement of trees.

Soil Management.—The soil management of tree fruit plantations must be adapted to the age of the trees, the general growth conditions and local conditions of soil and weather.

Fruit plantations are best established under arable soil conditions to encourage vigorous root and shoot growth. Exceptions to this are when a farm orchard of standard trees is established in grass or when grassland slopes subject to soil erosion are planted.

Arable Plantations.—The cultivations necessary can be carried out by the usual farm implements; as the trees grow, the depth of cultivation should be decreased and finally only shallow cultivations should be given over the whole area, otherwise serious damage to tree roots may result.

Spring and early summer cultivations are the most important and should run preferably in crosswise directions to cut down hand labour.

The small area round each tree which cannot be covered by implements should be hand-cultivated two or three times a year, care being taken that soil is not hoed away from the trees.

It is general practice to allow weeds to grow unchecked after the end of July and to turn in the growth during the winter "clean-up." In any case once fruit crops are carried it will be found increasingly difficult to carry out cultivations after August, and a weed-covered surface is preferable to loose soil when pickers with ladders etc. need to move freely and quickly about the plantation.

Apart from the ploughing of shallow furrows to drain off surface water, winter cultivations can be delayed until pruning and spraying are completed, the weed cover making the winter work easier to perform. The tree alleyways should then be shallow-ploughed or disced, and fertilisers applied before early spring cultivations begin.

Cover Crops are especially useful for the maintenance of soil organic matter and provide an alternative to a natural weed cover for this purpose. The crops usually grown are spring vetches, mustard, rape and winter rye. All need the usual seed-bed preparation, but they should be turned in whilst in a soft, lush condition, and 1 cwt. of nitro-chalk, sulphate of ammonia or calcium cyanamide per acre should be broadcast over the crop before it is turned under.

Grassing Down.—Apple and pear plantations established under arable soil conditions may be grassed down from about the eighth year, depending upon the size and vigour of the trees. Where trees have grown very rapidly and where canker has appeared, it may be beneficial to grass down at an earlier date.

In districts with an annual rainfall of 25 inches and over, and especially in the West of England where the rainfall may be as high as 35 inches, grass offers outstanding advantages over arable forms of cultivation for established trees. With apples, better colour and keeping quality result from grassed plantations and other advantages are ease of working at any time of the year, maintenance of organic matter, cheaper management costs coupled with better control of tree growth and less likelihood of canker.

The soil preparation preceding sowing down should be thorough and a good tilth obtained on a well-firmed soil. Seeding may be done in April or late July, but the latter period is generally recommended.

A suitable seeding mixture is 12 to 20 lb. perennial ryegrass and 2 lb. wild white clover per acre.

Plantations in Grass may be managed under two main systems: (*a*) the grass may be grazed by livestock or (*b*) it may be treated as "sod-mulch," a system in which the grass is mown frequently throughout the growing season and is left on the ground to rot. On no account should grass be taken off as hay.

The first method is usually adopted in farm orchards. In the commercial plantation, the tree stems are too short to allow of cattle grazing

and sheep cannot be run under trees with less than a 4 foot 6 inch stem (i.e. half-standards) without risk of damage. Pigs are not satisfactory for similar reasons. They also tend to leave the surface in a very rough condition, necessitating discing and/or heavy harrowing to level the soil when they are removed. Their effect on the trees may also be unsatisfactory. Poultry, especially under the folding system, provide the best means of livestock management in orchards, and geese are also suitable.

Livestock must be taken out of a plantation before harvesting operations begin, and it is important, therefore, that there is alternative accommodation for a period varying from a few weeks to perhaps two months.

Grass must be mown whilst young and should not be more than 6 to 8 inches high. This necessitates frequent cutting, but if the grass is allowed to run up to the flowering stage it decays slowly and makes succeeding mowings difficult.

The ordinary cutter bar hay-mower can do the work very satisfactorily but the fact that a swath is left tends to kill out the grass beneath and to make cross mowings difficult, unless the cut grass is raked up around each tree as a mulch.

The gang-mower eliminates these difficulties and the grower with 25 acres or more of trees in grass would do well to consider gang-mowing as an efficient form of plantation management.

The squares of grass around each tree which cannot be mown should be cut down by hook or scythe in early summer and again in the autumn to prevent the establishment of thick grass tufts and of weeds around each tree.

Pest and Disease Control.—Since pests and diseases can seriously reduce both yields and quality of fruit crops, it is important that the fruit grower should be fully aware from the outset that pests and diseases will make their appearance, and that unless they are controlled any project is likely to fail. Control measures are important items in the annual programme of work which cannot be omitted.

The usual pests which occur in tree-fruit plantations are aphides of several species, caterpillar or winter moth and tortrix; sawfly and red spider, which attack both apples and plums, and capsid bugs which attack apples.

Diseases usually present are scab and canker on apples and pears, brown rot on apples and plums and silver leaf also on plums. The grower must be able to recognise the damage these pests and diseases do in order to apply appropriate control measures. Efficient methods of control are available and the recommended treatments must be carried out in a thorough manner.

These measures involve the use of sprays or "washes" applied with spraying machinery and although newly-planted trees can be sprayed effectively for a few years by means of small capacity machines, these

soon become quite inadequate and recourse must be made to powered pump machines in order to obtain adequate volumes and pressures.

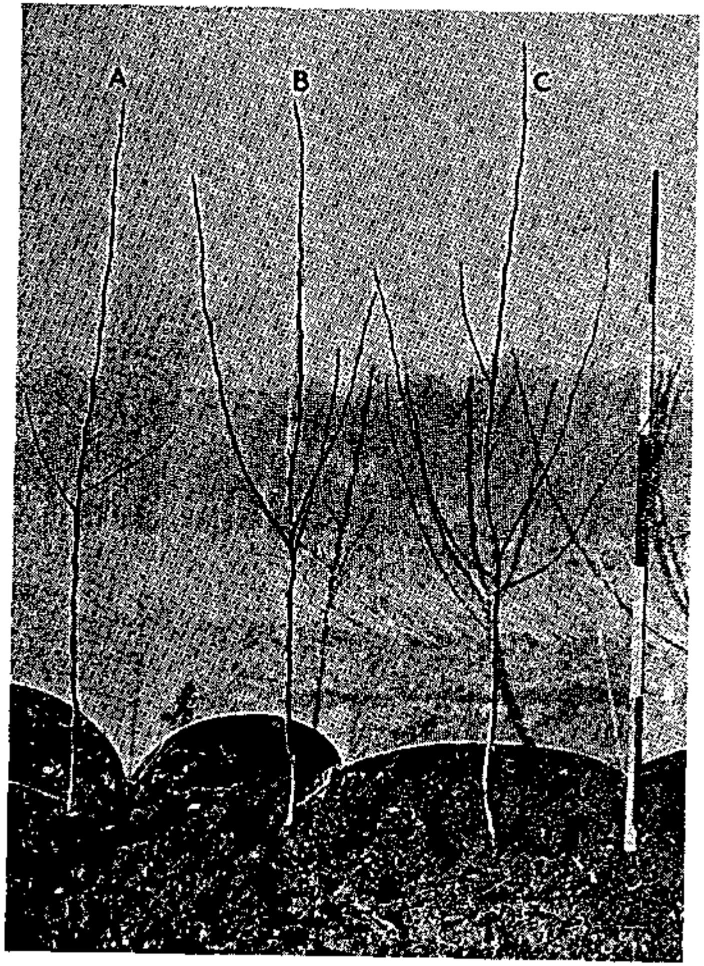
Three systems are adopted on the commercial fruit farm; (*a*) a completely mobile outfit consisting of tractor with power take-off and the actual spraying machine, comprising a pump driven from the tractor and a 200 to 300-gallon tank; (*b*) underground piping system fed from a stationary pump house, with standpipes at appropriate points and hose equipment (60 to 90-foot lengths); (*c*) automatic mobile spraying outfit, a relatively new method in which a powered machine, fitted with a series of adjustable nozzles is drawn through the plantation at a slow pace, spraying as it moves. All three systems have special advantages, and entail considerable capital outlay and maintenance costs.

To deal effectively with such pests as Apple and Plum Sawfly it is necessary to complete the spring-spraying against these pests in a matter of about seven to ten days. This is a critical period and failure to apply control measures promptly may result in a drastic reduction of crop. The size and capacity of a suitable spraying outfit, therefore, is closely related to this time factor and the size and area of trees to be covered. With a moderately-sized machine carrying 250 gallons of wash and a pump capable of delivering 17 to 20 gallons a minute from two spray lances, it should be possible to apply about 1,200 to 2,000 gallons of wash in a day—enough to cover about 2 to 3 acres of fully-established bush trees. Such an outfit, therefore, should be capable of coping with the spraying on approximately 20 to 25 acres of trees.

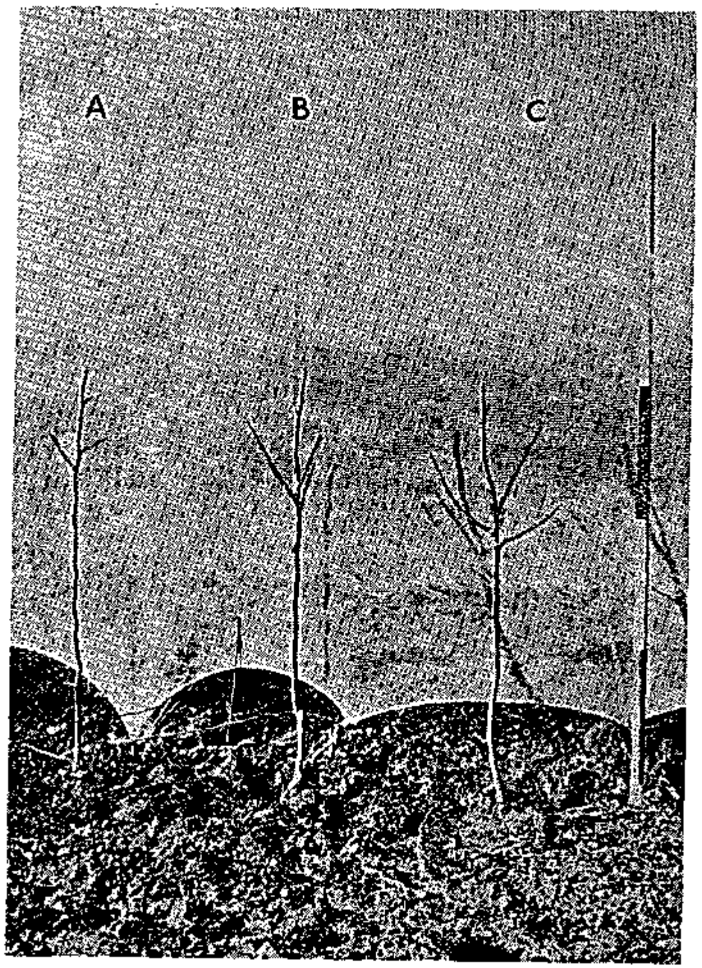
The labour required for the above machine would be a minimum of one tractor driver and two men, and, as the work cannot be fitted into odd periods, this labour would be occupied full time on spraying at peak periods. On the all-apple farm it can be estimated that 25 acres of trees would occupy the spray gang of three men on about forty to forty-five days in the year, the programme involving one winter and three or four summer sprayings.

Spraying is a dirty job and winter washes can quickly ruin clothing. It is usual, therefore, to pay a special bonus to cover such wear or for the grower to supply protective clothing. The farmer who intends to plant fruit should bear these points in mind and if only small areas are to be planted recourse should be made to contract spraying. Winter washing can be accomplished satisfactorily by contract, but the difficulties of completing efficient spring and early summer spraying on particular dates are obvious where one machine is shared by several growers, and the ideal is to plant a sufficient acreage to warrant equipment for the unit.

The greatest call on water is in spring and early summer when, for example, pre- and post-blossom sprays are needed for apples and a minimum of 2,000 gallons should be obtainable for each acre during this period. An ample water supply is therefore essential, and any natural



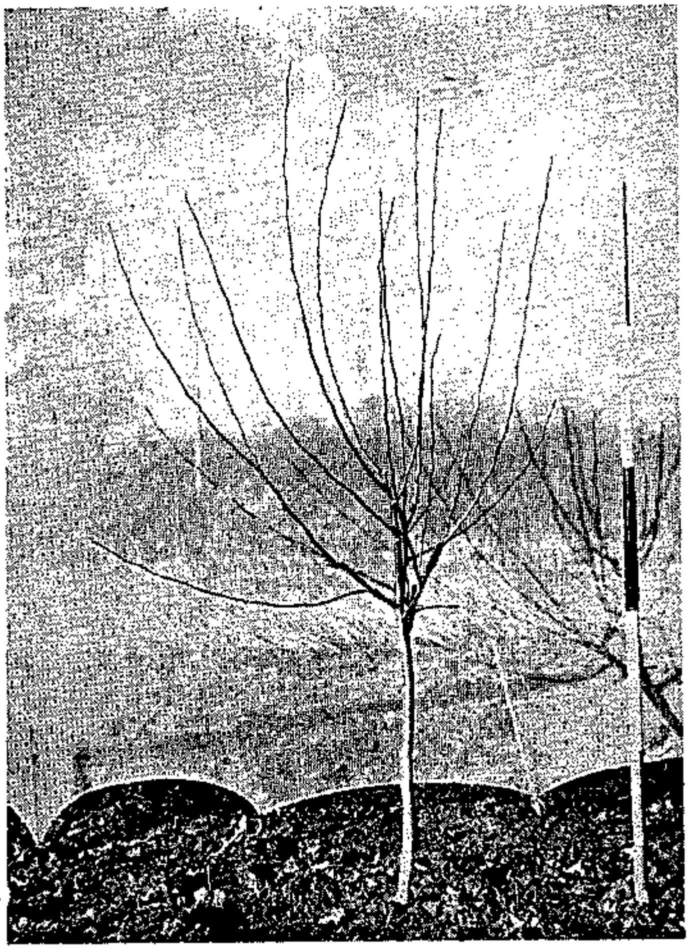
"Feathered" maiden A, B and C two-year-old trees.

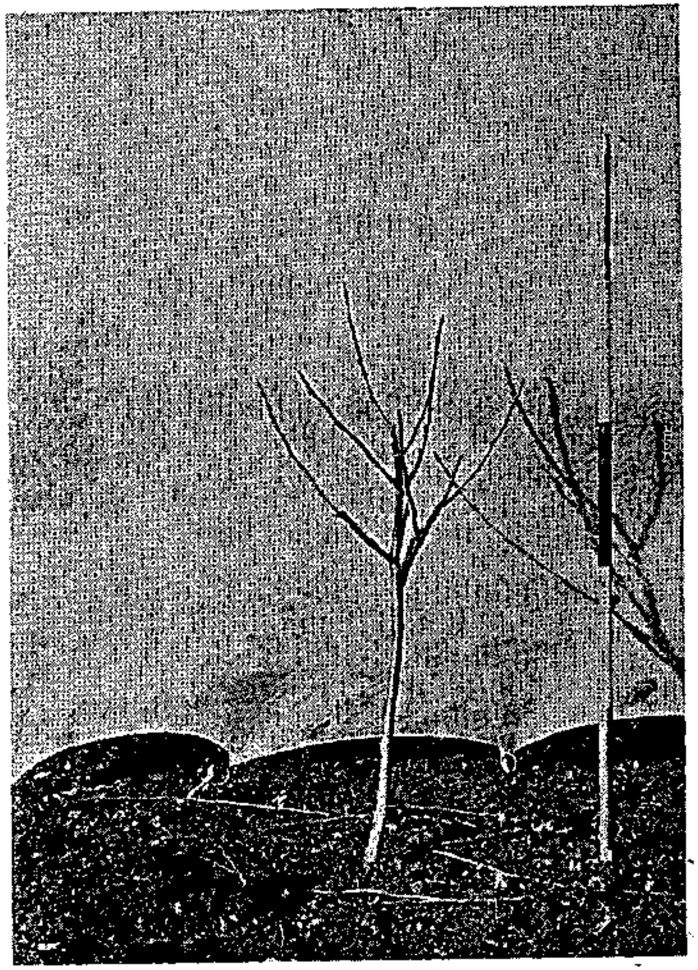


Trees A, B and C after pruning.

Development of young apple trees.

(Both by permission of Long Ashton Research Station.)


Three-year-old tree before pruning.


Three-year-old tree after pruning.

Development of young apple trees.

(Both by permission of Long Ashton Research Station.)

sources of supply on the farm should be exploited to conserve supplies in the spring and summer months in particular, when spraying calls for additional supplies.

FRUIT TREE PRUNING—GENERAL PRINCIPLES

The first object in pruning a tree is to shape it to some desired form, e.g. standard or bush. When this is done the next aim is to encourage the tree to bear fruit where it is wanted and subsequently to maintain the tree in a healthy fruiting condition for as many years as possible.

The first stage involves a hard pruning of shoots to form branches, a time when "leaders" only, i.e. branch extension shoots, are concerned. The second stage begins as soon as the tree has become sufficiently established and suitably furnished with a young, but developing, framework of branches to carry a crop. During this period pruning should become progressively lighter and involves both "leaders" and lateral shoots.

In the case of cherries and plums, pruning in the accepted sense may cease in three to five years after planting, and with standard apples after about six years, but with bush apples of moderate growth, pruning of leader and lateral shoots may be necessary over many years.

The third period covers the major portion of the life of the trees, and in this stage standard apples, pears, cherries and plums generally need only the removal of dead, broken or crossing branches.

Tree Shaping.—To begin shaping a maiden tree as a bush with a 2½ to 3-foot leg all that is necessary is to cut off the one main shoot just above a bud at the required height above ground. If any "feather," i.e. side shoots, arise below this point they may be shortened to two or three buds so as to form branches at suitable points. This hard cutting has one main object—to encourage an increased number of strong shoots from certain points, and in the following winter the maiden becomes a two-year-old tree with a one-year "head."

Half-standard and full standard trees are best trained as such in the nursery and bought for transplanting with a one-year-old head. In the case of half-standards this usually means a two-year-old tree if of plum or cherry, and a three-year-old tree of apple and pear. Full standards, with a one-year-old head have usually taken two to three years to form the main stem.

Practically all these types of tree start their actual branch formation in a similar manner and it is necessary at the first pruning to select a few of the best-placed shoots and to prune them back fairly hard to outward-pointing buds. The first branch shoots should arise from a reasonable length of stem to give strength at the point where branches fork from the main stem.

In the winter following the first pruning the number of shoots may be doubled and the strongest and best-placed of these should be retained

to extend the branch formation, pruning away about one-half to two-thirds of each shoot.

Standard Trees, whether apple, plum or cherry, are not usually "tipped" once a sufficient number of main branches have been formed to develop and carry a strong, well-balanced head. Once leader tipping ceases it will be necessary to thin out annually any overcrowded or crossing branches, broken or dead shoots, and to keep the tree reasonably open to the access of light and air.

The centre of the tree should be kept lightly filled with branches as, with cropping, the head will gradually open outwards, which results in a flattened top unless successive branch systems can act as replacements from the centre.

Bush Apples and Pears.—Leader Treatment.—Dessert varieties of apple, such as Worcester Pearmain, until well established, should be leader-tipped annually (*a*) to prevent tip fruiting of the leaders, which spoils the tree shape, and (*b*) to avoid long lengths of branch, without lateral growths, which result from non-tipping of the leaders. Cox's Orange may have a proportion of its leaders tipped and a few of the stronger ones left intact each year. This variety, however, "buds up" very freely along young wood in the second year and the branching system can best be retained and extended by a general tipping of the leaders. Laxton's Superb responds best to annual leader-tipping, otherwise branches become too weak to hold a crop.

Strong-growing cooking varieties such as Bramley Seedling and Newton Wonder require little or no leader-tipping after the first few years. Lateral growths can be left intact where there is room, overstrong competing shoots being cut clean out at the base. The annual pruning in the case of such trees generally involves saw work only, removing crossing branches and broken and dead wood. Some of the less vigorous-growing cooking varieties, like Emmeth, Grenadier and Crawley Beauty, often need a long period of leader-tipping to prevent the trees overcropping and being pulled badly out of shape.

Pears should be leader-tipped annually at least until they are fully-grown trees. The degree of tipping will vary with varieties, but most grow rapidly and form plenty of lateral shoots and spurs with a degree of tipping just sufficient to prevent the branches becoming too slender and weak.

Treatment of Laterals.—Modern pruning aims at fruiting apples largely on a constant succession of lateral shoots instead of cutting these back annually. The success of this system depends on the annual renewal of new shoots, a proportion of which is retained at each winter pruning and a proportion cut back to encourage further shoot growth. The system differs markedly from the old method of building up more or less permanent and constantly-ageing spur systems, which is now regarded as too drastic. If about one-third of the laterals up to 18 inches in length are

left unpruned each year and are well spaced along the branches, they should carry sufficient fruit buds by the end of their second growing season, when some may be reduced in length to avoid overcrowding and to provide a limited number of fruits for the following year. These laterals may fruit for a few years before being cut back hard to encourage new growths from the main branches which are subsequently treated in like manner.

One-year laterals surplus to requirements for fruit bud growth are shortened back at the winter pruning to three or four basal buds in order to encourage new shoots for the following year, so that young shoots are always available for selection as fruiting laterals in successive years. Short shoots up to 3 or 4 inches in length should be left intact, and overstrong laterals are best cut out at the base.

Most varieties of pears will fruit well under a similar system of lateral treatment, but overcropping often results in limb breakage and distortion of the branches. It is better therefore to shorten back all laterals over 8 inches to three or four buds from the base or to short sub-laterals which often form on one-year shoots. Short growths a few inches long and self-formed spurs should be left unpruned, since they will fruit without further attention.

THE APPLE PLANTATION

Dessert and culinary apples can be grown successfully over wide areas of the country, but north of a line from the Wash to the Mersey, and in Wales, plantings should be generally restricted to culinary sorts.

Type of Tree.—For the farmer fruit-grower, plantations of the bush type of apple tree are most suitable and intensive systems using dwarf pyramids and cordons should not be attempted.

Bush trees are easy to manage and with suitable planting distances they are preferable to longer-stemmed trees. They are usually grown on a "leg" or stem about 2 feet 6 inches to 3 feet in height. Shorter-stemmed trees are less easy to protect from rabbits by wire-netting collars, and do not allow easy working of implements beneath the lowest branches.

Rootstocks.—For soils of good depth and fertility and where exposure to wind is not likely to be a major factor, East Malling Type II rootstock is preferred. It provides quick-growing trees which may bear appreciable crops in six years from planting. Two other rootstocks of note are East Malling Type I and Type VII. Bush trees of dessert varieties on these rootstocks should be planted at not less than 18 feet apart on moderate soils with a rainfall from 20 to 28 inches per annum and not less than 24 feet apart on good soils with a rainfall of up to 35 inches per annum.

For more exposed situations where good anchorage is important and where the grower is prepared to allow more room, East Malling Type XVI rootstock is recommended. This rootstock is also specially useful when growing trees in grass. It produces big trees which can yield from about the tenth year. Bush trees of dessert varieties on this rootstock should

be planted not less than 36 feet apart on any reasonably good soil, whilst 40 feet apart would be a better distance where fertility is high and a cooking variety such as Bramley's Seedling is grown.

Varieties.—Of the many varieties catalogued, very few have stood the test of commercial production or met a ready demand on the markets, and it is unwise to undertake plantings of lesser known sorts on other than a small scale. Varieties may be chosen to meet a special local demand, e.g. Worcester Pearmain for holiday resort markets, but the growing of three to five varieties effects a spreadover of harvesting, storage and marketing and in addition helps to solve problems of cross-pollination in the orchard.

The following varieties are suggested as being generally suitable for growing as bush trees throughout the country. They produce good trees under good management and fruit well. The list is short, but includes the best market varieties.

Culinary		*Dessert*	
E Grenadier ..	Aug. - Sept.	E Fortune	Sept.
E Bramley's Seedling	Oct. - Feb.	E Worcester Pearmain	Sept. - Oct.
M Newton Wonder	Nov. - Feb.	E Ellison's Orange ..	Oct.
L Edward VII ..	Nov. - April	E-M Cox's Orange ..	Nov. - Dec.
L Crawley Beauty	Dec. - April	E-M Laxton's Superb ..	Nov. - Jan.
		L Winston	Dec. - Feb.

E = Early flowering; M = Mid-season; L = Late.

The most difficult variety to grow well is Cox's Orange and farmers are not generally recommended to plant this variety until they have gained experience with other sorts or have soils on which the variety is already known to do well. Edward VII and Crawley Beauty both flower very late in spring and are useful where late frosts are likely to cause damage. The latt[illegible]ly recommended for planting on frosty sites. Fortune and Winston are new varieties and initial plantings should be on a small scale.

Pollination.—Apple varieties differ in their ability to set fruit with their own pollen. Worcester Pearmain, for example, is highly self-fertile, whilst Bramley's Seedling will not set heavy crops unless cross-pollinated with another variety. No varieties are known to be inter-sterile, as in the case of certain plums and cherries.

It is best to assume, however, that no apple plantation will reach its highest degree of cropping without provision for cross-pollination, and it is necessary, therefore, to choose two or more varieties which flower approximately at the same time and to plant them alongside one another. The simplest arrangement is to plant them in blocks, up to four rows wide of each variety, repeating the arrangement throughout the plantation. Where a greater bulk of one variety is needed, blocks of four rows of the one variety can be interplanted with one row of the pollinator. This arrangement is an effective one and does not complicate the organisation of orchard work such as pruning, spraying and picking.

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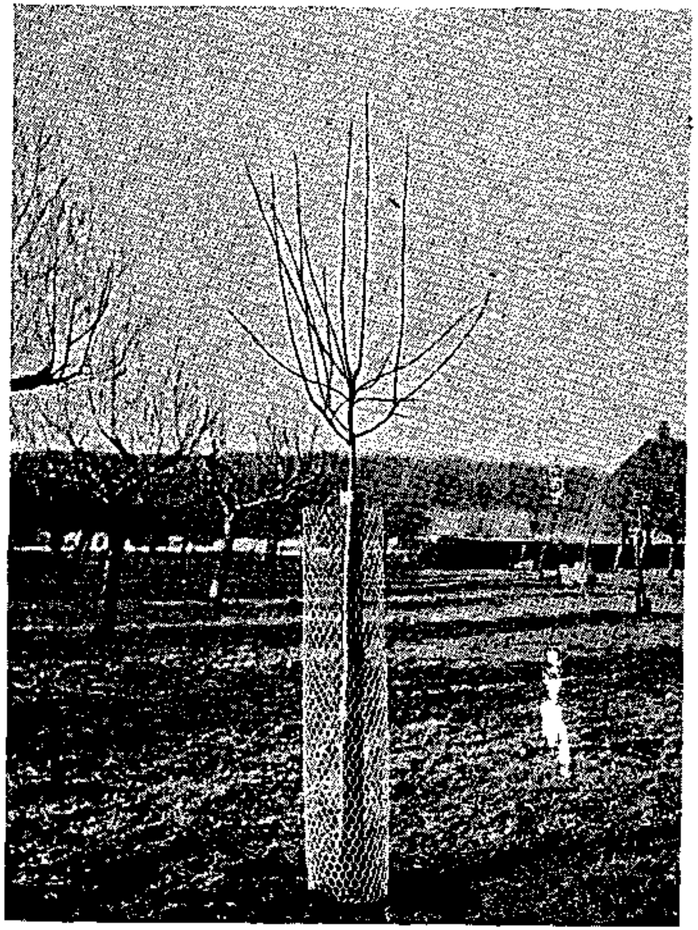
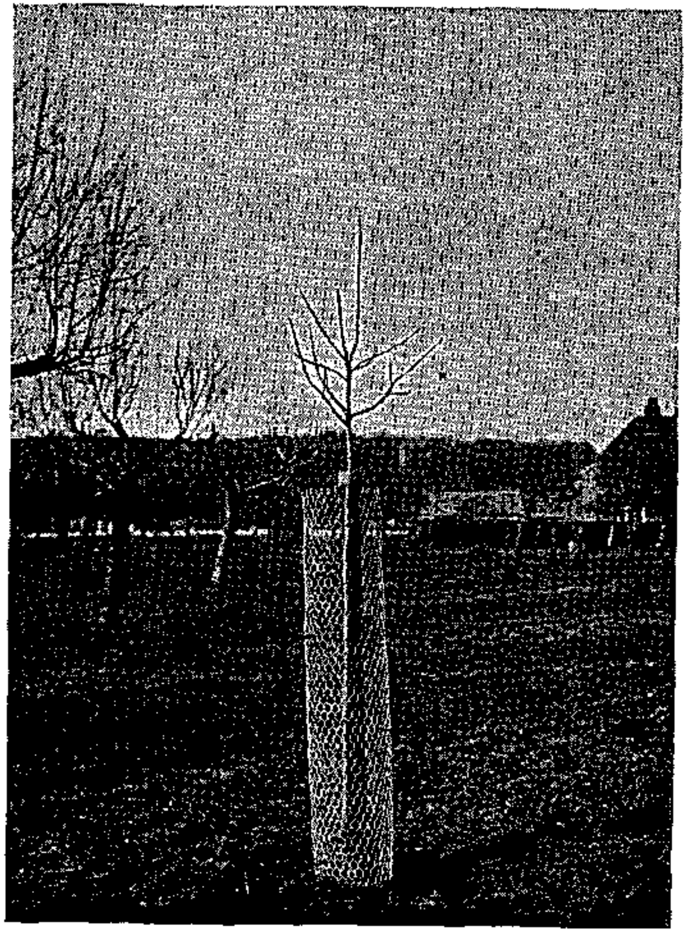
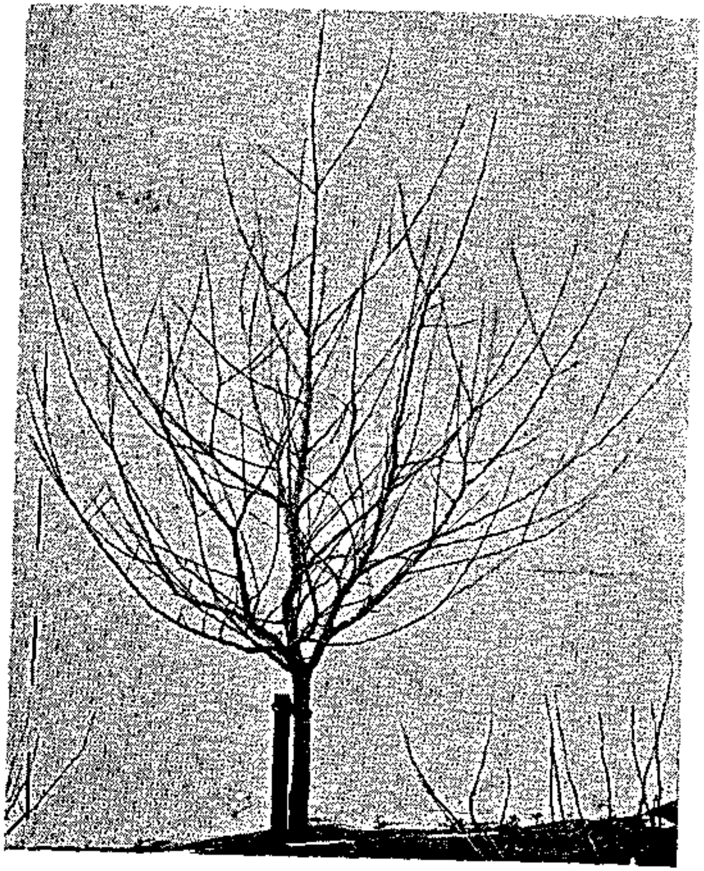


Young standard apple tree with two-year-old head, before pruning.

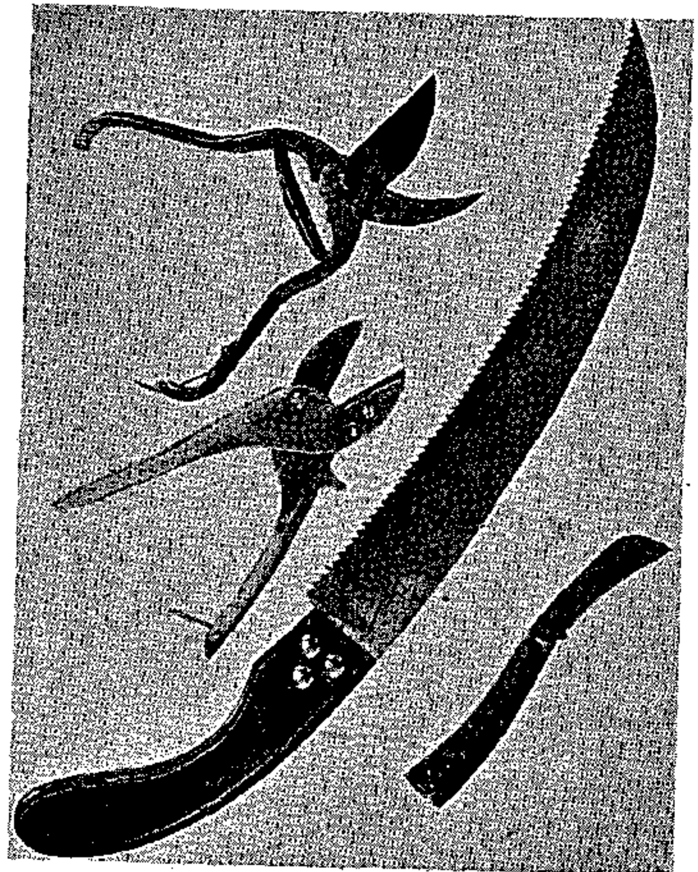


The same tree after pruning.

(*Both by permission of Long Ashton Research Station.*)



A six-year-old bush apple tree; note limb formation.



Good types of pruning tools.

(Both by permission of Long Ashton Research Station.)

Planting Plan.—Dessert and culinary varieties should be grown separately since they require different cultural treatment, especially manuring. The block system of planting as recommended under "Pollination" would, however, enable a dessert variety like Worcester Pearmain to be used as a pollinator for Bramley's Seedling.

Square planting is advocated, but the grower may wish to adopt some form of interplanting. Until comparatively recently it was common practice to underplant fruit trees with currants, gooseberries, strawberries etc., but such practice is not considered sound today. The best interplant, if one is necessary, is to include "filler" trees of apple in the main plantation, and to remove them before they interfere with the permanent plant. The simplest method is to plant an additional tree in the centre of each square of permanent trees forming a "quincunx" plant. Such an arrangement is only suitable, however, when the trees on the corners of the squares are not less than 20 to 24 feet apart.

It is important that fillers are not relied upon for cross pollination of the permanent plant, as their removal in later years to prevent overcrowding would upset the pollination arangements in the orchard.

Manuring and Soil Management.—Manuring and soil management are interdependent, and manuring must be adjusted to cultural practices.

Apples cannot be grown successfully on soils deficient in potash, and on most soils potash fertiliser must be applied annually to ensure satisfactory development of the trees and good-quality fruit. Annual dressings of 1 to 2 cwt. sulphate or muriate of potash per acre are usually sufficient and may be applied at any time of the year.

The requirement for phosphate is low and can be met by occasional dressings of superphosphate at 3 cwt. per acre.

The nitrogen requirement will depend upon such factors as the condition of the trees, the varieties and the method of cultivation. Under arable conditions trees can usually be kept vigorous with dressings of 2 to 3 cwt. per acre of sulphate of ammonia or its equivalent, whilst under grass the dressing may need to be as high as 4 to 6 cwt. per annum. Dessert varieties, on the whole, require less nitrogen than the culinary sorts, since a high nitrogen condition tends to produce green fruits.

The newly-planted orchard usually has sufficient humus, through the ploughing in of crop residues or of turf, to last several years but continued clean cultivation in plantations will eventually result in a deficiency of organic matter. This may be prevented by ploughing in weeds or cover crops or by the grassing down of the plantation as soon as tree condition permits.

Pest and Disease Control.—The spray programme in the apple plantation comprises one winter washing to control aphides, sucker, capsid bug and red spider (and to a lesser degree winter moth) and at least two and probably four spring and early summer sprayings to

control scab and sawfly and any capsid and winter moth caterpillar which escaped the winter spraying.

Winter washing may be carried out from early December until bud burst, which time will vary with the season, but it is wise to complete application with tar oil washes by the end of February.

If apple blossom weevil is a known pest it may be controlled by the application of a D.D.T. wash at or just before bud-burst. If the D.N.C. petroleum wash is applied just before bud-burst the D.D.T. may be added to the wash.

Spring and early summer washing must be done expeditiously, and in inclement weather it may be necessary to work overtime to ensure completion of the work at the right time. It should be possible with apples and plums to cover the whole area of trees in a week or ten days at the pre-blossom and post-blossom spraying periods and this necessitates the matching up of the equipment to suit the acreage.

The following spray programme is based on recommendations by Long Ashton Research Station.[1] Sprays 1, 3, 4 and 5 are the minimum number on which clean fruit can be produced, but in many parts of the country all six sprays may be required.

	Approx. date	*Stage*	*Materials per 100 gals. wash*	*Pests and diseases controlled*
(1). (*a*)	Dec. - Feb.	Dormant	5-7½ gal. tar oil emulsion	Aphides, sucker
or (*b*)	Feb. - mid-March	Up to bud break	7½-8 gal. D.N.C. petroleum emulsion	Aphides, capsids, red spider, winter moth
(2).	Mid-April	Green cluster	2½ gal. lime sulph., 2 lb. lead arsenate powder	Scab, winter moth caterpillar, tortrix caterpillar
(3).	Early May	Pink bud	1½-2 gal. lime sulphur	Scab
(4).	Late May	80 per cent. petal fall	2 gal. lime sulphur, 8 oz. nicotine wetter	Scab, sawfly, red spider, capsids, mildew
(5).	Early June	Fruitlet	¾-1 gal. lime sulphur	Scab, mildew

Harvesting.—Early varieties of apples quickly lose condition and will not store and should be marketed as soon as possible after picking. The picking of late varieties should be delayed until September-October to obtain good size and quality.

Early cooking varieties like Grenadier should be picked whilst the fruits are green; if left on the trees too long the fruits become yellow-green in colour and lose market value.

Dessert apples of early varieties such as Fortune and Worcester should not be picked until the fruits are at least half-coloured, the first fruits

[1] "A Summary of Fruit Spraying Programmes," 1942 Revision, by H. G. H. Kearns, R. W. Marsh, Long Ashton Research Station Annual Report, 1941.

being ready some time in early September. To obtain uniform specimens of high quality, growers usually pick over the trees two and three times clearing only well-coloured fruits at each picking. Later varieties like Ellison, Cox and Superb, should be left to colour well before gathering, the whole crop being removed in one pick.

Storage.—Long storage of apples does not pay except where a gas store is available, but varieties such as Bramley's Seedling and Edward VII can be kept in sound condition until January if the following rules are observed:

The store should be in a cool, frostproof building where the atmosphere can be kept moist by occasional damping of the floor with water. Ventilation should be arranged at floor level to admit cool air to the store, especially for the first week or so after filling with apples.

The store should be darkened and must be vermin proof. No permanent fittings in the way of shelves are necessary, but the apples should be stored in standard-sized boxes which will stack one above the other. Only sound, well-ripened fruits, free from insect and fungoid blemishes should be stored, otherwise losses will occur from shrivelling and rots.

Marketing.—Fruit marketing is a specialised business. The future trend is towards bulk marketing through the agency of central or co-operative packing stations run by growers. In this way growers can concentrate on growing high-quality crops which can be marketed relatively cheaply and successfully through an organisation specially equipped for the job.

THE CIDER ORCHARD

There are two main outlets for cider fruit, processing on the farm and selling to cider makers and apple juice manufacturers. In both cases the fruit should yield juice of special quality. It is usually best to grow a collection of sorts to produce juices of a sharp, sweet and bitter-sweet character respectively which, when suitably blended, give good quality ciders. It should be noted that for apple juice manufacture, bitter-sweet varieties are in special demand for blending with cull fruit from apple packing stations.

Type of Tree.—The usual cider tree should be a full standard with a stem at least 6 feet 6 inches in height. This allows of grazing by young cattle and sheep without damage to the trees. No tree, however, is safe if horses and horned cattle are used, and they must be excluded. Half-standards are well worth planting if grazing can be done by sheep only, but the stem must be a full 4 feet 6 inches in length to keep the tree-head out of reach.

Bush cider trees are at present under trial as a means of producing early cropping but a final opinion on their suitability cannot yet be given. If used, poultry could be run in the orchard.

Standard and half-standard trees should be worked on selected seedling

crab or Malling Type XVI, both of which give strong, well-rooted trees. Bush cider trees are also best worked on these stocks.

Varieties.[1]—Cider varieties are grouped into three main classes, sharp, sweet and bitter-sweet, according to the type of juice they yield. In general all three types are necessary to produce high-quality cider, although the variety Kingston Black and a few others yield juices of such balance that a cider of the highest quality may be obtained unblended. Unfortunately, Kingston Black requires very special conditions of soil and climate and cannot be recommended for large-scale planting.

Cider apples ripen at different periods, from August to December, and the time of "fall" is an important consideration when planning an orchard. On the mixed farm, for example, it is advisable to concentrate on late "falling" varieties so as to keep clear of potato and root harvest.

The following lists include early, mid-season and late-ripening varieties under the broad grouping of sharp, sweet and bitter-sweet. Those listed are only a small fraction of the large number of varieties grown in the cider orchards of the west and south-west, but with the exception of Kingston Black they are sorts known to do well generally and to give a good orchard tree.

Their juice quality is generally good although in certain varieties, e.g. Morgan Sweet, Bulmer's Norman and Court Royal, quality is not high but the yield of juice is good.

	Sharp	*Sweet*	*Bitter-sweet*
EARLY FALLING	Backwell Red, E	Morgan Sweet, E	Major, E; White Jersey, E; White Norman, E
MID FALLING	Kingston Black, M Red Foxwhelp, M Stoke Red, L Langworthy, M Porter's Perfection, M	Court Royal, E-M Sweet Alford, M Sweet Coppin, L Woodbine II, M (syn. Sweet Woodbine)	Bulmer's Norman, M (Harry); Masters Jersey, L; Yarlington Mill Jersey, L
	Fair Maid of Devon, M	Killerton Sweet, M	Royal Wilding, M; BrownSnout, M; Horner's, L (syn. Hangdown)
LATE FALLING	Crimson King, M Reinette Obray, L Lambrook Pippin, L	Woodbine I, E (syn. Slack-ma-Girdle)	Dabinette, L; Medaille d'Or II, L (Upright); Michelin, M-L; Reine des Pommes, L; Tardive Forester, E-M; Dove, L

The relative flowering dates are denoted thus: E=early; M=mid; L=late-flowering.

[1] For a full description of varieties the reader is referred to the Ministry of Agriculture Bulletin 104, "Cider Apple Production."

Apple picking; note types of steps, picking bag and orchard box.

Bush apple, Worcester Pearmain, twelve years on M II root-stock.

(Both by permission of Long Ashton Research Station.)

Pollination.—The same general provisions for adequate cross-pollination apply to cider varieties as for dessert and culinary sorts. On no account should orchards of a single variety be planted, and at least three varieties flowering approximately during the same period should occupy adjacent blocks.

Block planting in complete rows, not more than four rows per unit, is the best arrangement to provide for cross-pollination whilst at the same time facilitating harvesting operations.

Tree Spacing and Arrangement.—Standard trees need an average spacing of 36 feet. On good soils the stronger-growing varieties should be planted 40 feet apart, but on less fertile soils, and with the more compact-growing sorts, 30 feet may be sufficient. Since it is undesirable to plant at several different spacings in any orchard, 36 feet will be found generally suitable, and spreading, and compact or upright varieties should be alternated where this is possible.

From the viewpoint of grass management, and if the flowering periods permit, it is helpful to plant the early, mid-season and late falling varieties in separate orchards. In this way, grazing (or mowing) can be done close up to the time of ripening and the grass has no chance of becoming unduly long at harvesting and so making picking up tedious and costly.

Manuring.—Whilst the trees are young it will help, in addition to any mulching, to give an annual dressing of balanced N.P.K. fertiliser, which should be hoed in around each tree in March. Livestock should not be considered as helping much in the manuring of an orchard unless they are trough fed. The usual type of grazing will, in fact, slowly impoverish the orchard, so that the addition of fertiliser, especially nitrogen and phosphate, will be necessary to keep up soil fertility. Too high a nitrogen supply, however, has a detrimental effect on cider quality.

Pest and Disease Control.—The cost of a full spray programme as given for the commercial fruit farm cannot be justified in the farm cider orchard. An annual winter wash may be profitable and it may be necessary on some sites to apply spring sprays to check red spider and scab. Where the orchard has not been sprayed previously and is being renovated from a neglected state, a tar oil winter wash should be given as the first spraying as it will clean up moss and lichen.

For particulars of sprays and methods of application see page 199.

Harvesting.—The harvesting of cider apples begins with the falling of the fruit. Early fruit should be picked up every few days and taken to the mill. In practice, and for late varieties, however, it is usual to wait until about half the crop is on the ground and then to shake down the rest before picking up.

It is bad practice to shake down fruit which does not part readily from the trees as the fruit is not only immature, and therefore not of good milling quality, but numerous spurs will be broken from the trees.

Each variety should be picked up and if possible, bagged separately as the maker never welcomes consignments of mixed fruits.

Picking up can be done by piece-work where the crop is large. Rotten apples should not be included as they rapidly infect other fruit near them and unsound fruits make bad cider.

THE PEAR PLANTATION

The conditions recommended for apples apply, in the main, to pears. Pears, however, succeed on soils more retentive of moisture and of slower drainage but they need warm summer and autumn days to ripen the fruit satisfactorily.

Pears flower earlier than apples and shelter from cold exposures is valuable in spring, whilst in the autumn, shelter from autumnal gales reduces losses due to windfalls.

Pears should be grown as bush trees with stem length of 2 feet 6 inches so that pruning, picking and spraying operations can be done easily.

The pear crop needs special care in harvesting and marketing and if grown in quantity the fruit requires special provision for cold storage.

Rootstocks.—Quince A is the best all-round rootstock for bush trees. Some varieties, however, e.g. Williams Bon Chretien are incompatible on Quince and they must be either "double-worked" or grown on seedling pear rootstocks.

Varieties.—Few varieties are commercially profitable and many of the high quality sorts grown in private gardens are unsuitable for plantation culture. The following list of varieties, given in order of ripening, will meet normal marketing requirements. They all crop heavily and with the exception of Williams and Improved Fertility they are reasonably easy to keep free of pear scab.

L	Laxton's Superb	early August
M	William's Bon Chretien ..	August
L	Improved Fertility	end August
M	Bristol Cross	September
M	Conference	September - October

The variety Doyenne du Comice, a pear of superb quality, is not recommended other than under specially good conditions of soil and climate as it usually crops too lightly to be profitable.

Pollination.—Few pear varieties set satisfactory crops with their own pollen, and varieties which flower during the same period, or which overlap, should be planted together to effect cross-pollination. The best arrangement of trees to effect pollination is the block system as recommended for apples.

Planting Plan.—The trees should be spaced 18 feet apart. This arrangement allows of no "filler" trees and no undercrops of soft fruits should be undertaken.

Manuring.—Pears require a high level of manuring and cultivation. In general they require higher nitrogen applications than apples, but their potash and phosphate requirements are similar. Where inorganic fertilisers are relied upon, annual dressings of 2 to 4 cwt. per acre sulphate of ammonia or nitro-chalk, 1 to 2 cwt. per acre sulphate or muriate of potash, and 2 cwt. per acre superphosphate are generally recommended.

Where organic fertilisers or dung are available, it may be possible to lower the fertiliser dressings to some extent, but bulky fertilisers should be valued mainly for their physical influence on soil structure. Where annual rainfall allows, pears may be grassed down after about ten years of arable cultivation.

Pest and Disease Control.—Pears are subject to comparatively few pests and diseases and the spray programme to control them is a simple one. The worst enemy is scab, and unless this disease is controlled, pear growing will fail.

Sprays 1 and 3, 4 and 5 (less nicotine and lead arsenate) recommended for apples will provide all the control measures normally necessary. Conference, which is an almost scab-free variety may need only sprays *1(a)* or 1(*b*) in some localities but Williams and Improved Fertility will almost certainly require the full programme.

Harvesting.—All varieties need picking in firm condition and experience is needed to decide the optimum stage of ripeness for picking. Laxton's Superb, William's Bon Chretien and Improved Fertility must be marketed straight from the tree whilst still hard. Bristol Cross and Conference should be left on the trees until the fruits begin to fall. Both varieties may be held in cold store to extend the marketing period.

THE PLUM PLANTATION

Plum growing fits in well with general farming provided labour requirements at picking time, i.e. August-September, can be met without drawing staff from essential farm work.

Plums grow particularly well on heavy soils with satisfactory drainage on which the trees are usually longlived and attain large size under good cultural conditions and the fruit is of good quality.

Plum trees grow quickly and may start bearing in four to five years from planting and remain in cropping for thirty or more years. Most varieties are in blossom during April so that a reasonably sheltered but frost-free site is a prerequisite to good crops.

The farmer-fruit grower will find cooking varieties to be the easiest to grow, and although prices for them are lower than for dessert sorts, their production and harvesting costs are lower. Cooking plums, however, are already produced in large quantities and intending planters would do well to consider the planting of a proportion of dessert plums.

Type of Tree.—Plums are best grown as half-standard trees, with a main stem of 3 feet to 4 feet 6 inches in length. This length allows for the

drooping habit of many varieties, especially when laden with crops, and also ensures easy access for cultivating machinery.

Full standards are grown in some districts but such a long stem is unnecessary except where special under-tree clearance is necessary, e.g. for livestock in the grassed orchards or where plum trees are planted as windbreaks.

Rootstocks.—Plums are propagated on many different rootstocks but only Myrobolan "B" and Brompton, strong, well-anchored rootstocks which produce very vigorous trees, and Marianna, Pershore and Common Plum which provide quick fruiting but less vigorous trees, need be considered. Myrobolan "B" is the best rootstock for trees to be planted and maintained in grass.

Common Plum is of special value as a rootstock for Victoria where Silver Leaf is troublesome, but the varieties Czar, President, Pond's Seedling and the Damsons are incompatible on this rootstock. Marianna, too, is not suitable for all varieties and Czar, Oullin's Golden Gage, President and the Damsons should not be worked on it. Pershore can be used with all varieties.

Varieties.—The following lists, in order of ripening, provide sufficient selection to cover commercial needs. The culinary varieties are well known but the dessert kinds have not been grown so extensively or under so great a range of soil and climatic conditions. They are, however, varieties of good quality and can crop heavily under favourable conditions. Since mid-season cooking varieties are already grown in quantity, preference should be given to early or late ripening sorts.

	Culinary		*Dessert*
E	†Early Laxton, July	L	†Oullin's Golden Gage, early August
E	River's Early Prolific, July-August	E	†Early Transparent Gage, end August
M	Czar, mid-August		
M	†Pershore (Yellow Egg), mid-end August	E	†Denniston's Superb Gage, mid-August
M	*Victoria, August-September		
E	†Warwickshire Drooper, end September	L	†Cambridge Gage, end August
M	†Giant Prune, end September		
L	†Marjorie's Seedling, October		

* Classed as a cooking variety but good samples are popular for dessert.

† Varieties specially recommended. E=Early flowering. M=Mid-season. L=Late flowering.

One variety of Damson only is recommended—the Prune Damson (variously known as Shropshire, Cheshire or Westmorland Prune Damson). It is unsurpassed for flavour and is the only variety in demand by the processor.

Pollination.—The special problems of pollination concern self-sterility and the fact that certain varieties fall into inter-sterile groups, but even varieties which are highly self-fertile, Victoria for example, should not be planted as single varieties in large blocks.

Varieties which flower over approximately the same period should adjoin each other, and of the varieties listed above, any four, which included Victoria, if planted together would provide for adequate cross-pollination.[1]

Planting Plan.—The recommendations given for apples apply in general to plums. Planting distances depend on soils and rootstocks. Where growth conditions are good, and especially where Myrobolan or Brompton rootstock is used, 20 feet square in grass and 24 feet square under arable conditions are suggested as suitable arrangements.

Where Pershore, Marianna or Common Plum rootstocks are used a 24 feet quincunx arrangement is suitable and would allow of thinning out at a later date. On soils where tree growth is not rapid the above arrangement is also preferable to the popular 18 feet square plant.

The ground between newly-planted trees can be cropped with potatoes, summer vegetables or fodder root crops for the first three to five years and this is preferable to undercropping with fruits, provided the land is free in the winter to allow of winter spraying.

Manuring.—Plums require a high nitrogen level and adequate supplies of potash to prevent leaf scorch, and occasional dressings of phosphates are also required. Plums under arable conditions need annual applications of nitrogen and nitro-chalk or sulphate of ammonia (the latter on lime-sufficient soils) at the rate of 4 to 6 cwt. per acre per year should be applied in March-April. Where humus is deficient and soil texture poor, nitrogen may be given as wool shoddy at 40 cwt. per acre, or meat or hoof meal at 8 cwt. per acre applied annually. A suitable annual potash dressing would be 1 to 2 cwt. muriate of potash per acre, whilst 5 cwt. superphosphate every third year will suffice. Under grass the nitrogen required may amount to 8 to 10 cwt. S/A per annum applied in early February; in addition 1 cwt. muriate of potash annually with superphosphate at the rate of 2 to 3 cwt. per acre every two or three years should be given.

Pest and Disease Control.—The usual pests are aphis, red spider and winter moth, all of which are effectively controlled by winter washings with D.N.C. petroleum, and sawfly, which is controlled by a derris-white oil emulsion wash at the "Cot" split stage (usually in May). Winter washing with D.N.C. petroleum may safely be done as late as mid-February, but if for special reasons a tar oil winter wash is used, the work should be completed by the end of January.

Effective control of plum sawfly depends on applying the derris-white oil emulsion spray within about seven days of the "Cot" split stage, which

[1] For further information see Advisory Leaflet No. 4, "Fertility Rules in Fruit Tree Planting," issued by the John Innes Horticultural Research Institute.

generally takes place some ten days after petal fall. The spray should be directed forcibly into the fruitlet clusters. Winter moth, caterpillar or red spider are also controlled by this wash.

The following spray programme should cover normal requirements for plums.

Stage	Approx. time of spraying	Materials per 100 gals. wash	Pests Controlled
Dormant	Dec. - Jan.	5-7½ gal. tar oil emulsion	Aphides
Dormant	Up to mid-Feb.	5-7½ gal. D.N.C. emulsion	Aphides, red spider, winter moths
"Cots" splitting	Mid-May	"Derris" 1 gal. white oil emulsion	Plum sawfly, caterpillar, red spider

Propping.—In years of heavy crop and especially with young trees, propping should be a routine practice. The simplest method is to use forked poles, as cut from the woods, of appropriate length (about 6-10 feet) with which to support the branches.

Harvesting.—Plums should be picked when well-coloured but firm and ripe. The variety Pershore (Yellow Egg) is unusual in that it should be picked before it turns a lemon yellow colour after which it loses its good cooking and processing qualities.

Dessert plums and gages should be ripened more fully on the trees before picking, provided sufficient labour is available to clear the crop quickly before the fruits become too soft. Gages need carefully watching when near ripe as they soften quickly and may become useless in the matter of a day or so. Picking must be done while the trees are dry and in hot weather the picked fruit should not be exposed to hot sunshine for any length of time as it easily becomes scorched.

The usual market containers are the half sieve holding 24 lb. and the 12 lb. or 6 lb. chip basket. Processing plums, Pershore in particular, are often marketed in shallow trays holding about 36 lb. Dessert plums are best picked direct into small containers such as the 4 lb. or 6 lb. chip basket.

THE CHERRY PLANTATION

Only well-drained soils of reasonable depth should be considered for cherry growing, and it is important to plant only in areas where early summer rainfall is not heavy, otherwise heavy loss of crop may result from fruit splitting on the trees. Shelter from the east and north east is valuable as cherries flower early in the year, but exposure to autumn gales is of less consequence.

As birds may completely strip isolated trees or small plantations of fruit, it is necessary to plant a large enough acreage to warrant full protection, and 5 to 10 acres is suggested as a minimum.

Type of Tree.—The full standard has invariably been planted in the grass orchard as it allows of livestock grazing beneath the trees. Latterly, some growers have planted bush trees on a 3-foot leg and this type offers considerable advantages over the standard tree to the specialist fruit grower. Grazing, of course, cannot be done but sod-mulching methods give good results; the trees reach good size and bear more quickly, and they are also less costly to stake, prune and pick than full standards.

Rootstocks.—Nurserymen usually bud or graft cherries on the wild Mazzard stock which provides a well-anchored tree. The stock is raised freely from seed.

East Malling Research Station has introduced a particularly useful vegetatively propagated rootstock, F.12/1, which is highly satisfactory. Once this stock is better known it will largely supersede the Mazzard.

Varieties.—Cherries are a highly perishable crop and it is most desirable to spread the picking season over several weeks to ease the demands on labour. It is also particularly necessary with sweet cherries to grow a range of varieties which will ensure adequate cross-pollination.

The varieties listed below, in approximate order of ripening, are recommended as succeeding generally. In choosing varieties for a large plantation, a good proportion of late ripening sorts should be included to warrant the continued bird scaring which will be necessary after the early kinds are picked.

Early Rivers (1)	*M*	*Season*	*mid-June*
Governor Wood (4)	L	„	mid-end June
Early Amber (4)	E	„	end June
Frogmore (2)	L	„	end June-July
Waterloo (2)	E	„	early mid-July
Roundel (1)	L	„	mid-July
Gaucher Black	E	„	mid-July
Late Amber	E	„	mid-July
Noble	L	„	mid-July
Bigarreau Napoleon (3)	L	„	mid-late July
Emperor Francis (3)	E	„	mid-late July
Florence Heart	L	„	late July
Bradbourne Black	E	„	late July
Ohio Beauty (3)	M	„	end July-August

E = Early flowering; M = Mid-season; L = Late flowering.

In addition to the above, the following five new varieties arranged in order of picking are seedlings raised by the John Innes Horticultural Research Institute. Each has been tried under field conditions and is worthy of trial commercially: Merton Heart, Merton Bounty, Merton Premier, Merton Favourite, Merton Bigarreau.

Pollination.[1]—Provision for cross-pollination in the cherry plantation is essential for satisfactory cropping since no variety of sweet cherry will set fruit with its own pollen. The problem is further complicated by the fact that varieties can be divided into groups within which the pollen of no one variety will fertilise any other variety within the same group.

In the case of the varieties listed above those with like numbers (in brackets) should not be planted together, but the varieties Gaucher Black, Florence and Noble are universal donors of pollen and can be planted with any variety.

Planting Plan.—On good soils, sweet cherries need a final spacing of 40 feet, i.e. twenty-seven trees per acre and this is suitable for either standard or bush cherries. Where local conditions suggest this to be too wide, a quincunx plant is recommended.

The best arrangement of varieties depends not only on provision for cross-pollination but also on arranging them in sequence of ripening. If picking can begin on one side of a cherry orchard and progress, variety by variety and row by row, until the opposite side is reached, the picking equipment needs a minimum of handling.

Pruning.—Except that the length of stem differs, standard and bush cherry trees are built by the same general methods of pruning. In young trees, well-spaced shoots should be retained to form the main branches, and if a more or less centrally placed shoot is retained for a year or two, further branches can be built along it to form a strong tree head.

Pruning is best done in late summer, whilst the trees are still in leaf, or may be delayed until growth has started the following spring. By these procedures the possibility of infection from silver leaf is minimised.

Manuring.—The manuring of cherries must be liberal to grow fruit of high quality, although overdoses of nitrogenous manures may cause serious splitting of the fruit in wet seasons and promote brown rot. The normal manurial practice in the past has consisted of annual heavy dressings of phosphates combined with the grazing of trough-fed sheep to return nitrogen and potash to the soil. Today trough feeding is neither practicable nor profitable, and annual applications of balanced fertilisers must be given, e.g. 2 to 4 cwt. sulphate of ammonia or nitro-chalk, 3 cwt. superphosphate and 1 cwt. muriate of potash per acre.

The sod-mulched orchard will generally need annual dressings of nitrogen and potash but as a sweet grazing herbage is not required, phosphatic fertilisers need only be given occasionally—say 5 cwt. superphosphate per acre every three years.

In arable plantations, organic dressings in the form of yard manure, compost or shoddy, or the discing in of cover crops, should be used to preserve a good level of organic matter in the soil. These practices should be supplemented with annual dressings of complete fertiliser in order to

[1] For detailed information on pollination the reader is referred to John Innes Advisory Leaflet No. 4, "Fertility Rules on Fruit Tree Planting."

build up the trees rapidly and improve the general nutritional status of the soil before grassing down.

Pest and Disease Control.—Sweet cherries suffer from comparatively few pests and diseases, the principal being aphides, winter moth, bacterial canker, silver leaf and blossom wilt.

Winter washing will give almost complete control of aphides and partial control of winter moth caterpillar. Caterpillar, however, is effectively and cheaply controlled on cherries by grease banding. Bacterial canker and blossom wilt may prove troublesome diseases in some areas, especially in the west of England where rainfall is high. Both diseases can be controlled by application of Bordeaux mixture before flowering and, in the case of bacterial canker, again in the autumn.

In the case of standard cherries, effective spraying can only be done by machines of sufficient power to reach the tops of the trees and as much as 1,200 gallons of wash may be required to cover thoroughly an acre of mature trees.

The following spray programme will control the usual range of pests and diseases of cherries, but the winter washing is the only spraying likely to be necessary in all orchards.

Stage	Approx. time of spraying	Materials per 100 gals. wash	Pests and Diseases Controlled
Leaf fall	October	Grease banding	Winter moth caterpillar
Dormant (a) *or* Dormant (b)	Dec. - Jan. / Jan. - Feb.	5-7½ gal. tar oil emulsion or 7½ gal. D.N.C. emulsion	Aphides
White bud	April	Bordeaux mixture 8:12:100; lead arsenate powder 2 lb.	Bacterial canker, blossom wilt, caterpillar
Leaf fall	Mid-Oct.	Bordeaux mixture 8:2:100	Bacterial canker

Harvesting.—Cherry picking is usually done at piece-work rates by women working under the direction of a foreman who also acts as ladder mover. The ladder work requires considerable skill to avoid damage to the trees and accidents to pickers. Tall trees may need man labour as women will rarely undertake picking from very tall ladders. Ladders need to be light yet strong and the bottoms should be splayed outwards to give rigidity when set up. One of the big advantages of the bush form of cherry is that much of the crop can be picked from the ground or from low picking "stools."

Since the fruit is highly perishable, cherries must be cleared rapidly once they begin to colour, and marketing must be done whilst the fruit is in firm condition as it stands little handling when ripe. The usual market package is the 12 lb. cardboard or chip basket, although high-quality fruit is better marketed in 4 lb. or at the most 6 lb. baskets.

The grading of cherries is not practicable since the fruit cannot stand the necessary handling, but the foreman should see that damaged fruits, leaves or pieces of twig are not included in the baskets.

BUSH AND SOFT FRUITS

General Considerations.— Provided site, soil and climate are satisfactory and that casual female labour is available at picking time, the farmer may consider growing blackcurrants, raspberries and strawberries.

It is imperative to plant only sound disease-free stock, otherwise financial loss is certain. The Ministry of Agriculture has initiated schemes for the certification of blackcurrants, strawberries and one variety of raspberry which guarantee to the buyer nursery stock of a very high standard and growers are recommended to buy only certified stocks.

Planting is best done in blocks in the open and not under fruit trees, but if underplanting is contemplated, blackcurrants may be grown under plums, and strawberries can be grown with any of the tree fruits.

BLACKCURRANTS

Blackcurrants need a high level of fertility to be profitable. Normally they can be expected to give about ten crops on the commercial farm before they become unprofitable and the grower should make successive plantings on fresh sites every few years to replace older plantations.

Type of Bush.—Since blackcurrants fruit most heavily on the previous season's wood growth it is necessary to furnish the bushes with as much new wood as possible each year. This new wood can only be made when the bushes are formed largely of basal or "sucker" shoots from ground level, at least during the first six to eight years of the plantation's life, after which much of the young wood may grow as lateral shoots.

Planting Plan.—Two main systems are in vogue: (*a*) square planting, (*b*) hedge planting. Scarcity and cost of hand labour have been largely responsible for square planting becoming less popular, except where space is available for bushes at 10 feet square, and for cultivations and spraying to be done by tractor.

The alternative is to plant on the hedge system which is very popular in the west and is the best method on small acreages. A large number of bushes per acre can be planted under this system and it helps to increase crop returns appreciably for at least the first five years of cropping.

Walk-behind motor cultivators can operate between 8-foot rows but any wheeled tractor needs at least 10 feet to avoid wheel damage to outside branches. The planting distance in the row may be as little as 3 feet in the case of the 10-foot row spacing, and 4 feet is suitable in the 8-foot spacing. The former needs 1,455 bushes per acre and the latter 1,360 bushes.

A 10-foot alleyway allows the use of a mobile spray outfit but closer spacing eliminates this possibility and hoses have to be dragged between the rows from a sprayer standing on the headland. Since a 90-foot length of hose is enough for one man to handle on arable soil, the length of the rows should not exceed about 180 feet without provision of crossroads, which should be allowed for at planting time by omitting the planting of about three bushes in the row at regular distances.

Varieties.—On large acreages it is necessary to grow several varieties in order to spread the picking period as much as possible. The following short list includes early, mid-season and late ripening varieties of merit. All can crop heavily although one may be favoured more than another according to locality.

The varieties, in the order of ripening are: Mendip Cross, Seabrook's Black, Wellington XXX, Cotswold Cross, Baldwin, Westwick Choice.

Planting.—One- or two-year-old bushes can be planted any time from leaf fall until the end of February when the soil conditions are dry enough. Planting should not be attempted in frosty weather.

Correct depth of planting is important, and in order to establish a proper type of bush, planting should be deep enough to allow a few inches of young wood to be below soil level. On no account should bushes be planted so that a length of stem is left between soil level and the lowest branches.

Cultivations and Manuring.—All cultivations, after planting, should be fairly shallow and only sufficient to kill weeds.

Whenever possible, all hand-hoeing should be done by a heavy type of push hoe since it leaves the surface even or slightly mounded to the bushes.

Inter-row cultivation can be done effectively by horse-drawn implements working fairly close to the bushes, but where tractored tools are used they should be set for shallow work.

Pruning.—Newly-planted bushes should be cut down to within one or two buds of ground level before growth begins. This initial hard pruning is necessary to obtain the correct type of bush with shoots growing from below, or close to, ground level.

At the end of the first season, two-year-old planted bushes should have made three or more strong new shoots and these can be allowed to fruit in the following year. Odd bushes which make one or two shoots only should be cut down again.

After cropping for the first time, every shoot which has fruited should be cut out. This may mean cutting to ground level or back to a strong new lateral shoot. From the second year of cropping, pruning should aim at cutting out all shoots which have failed to make appreciable extension growth and to make one or more cuts to ground level according to the age of the bush.

No tipping of shoots or shaping of the bush beyond removal of very

low-positioned shoots is necessary and as little new wood as possible should be cut out since it is the young wood which fruits most heavily.

As the bushes age, from about the sixth year onwards, it may be impracticable to cut out shoots to the base without removing good lengths of young shoots higher up and pruning therefore tends to consist more and more of shortening back poor-growing shoots to good lateral growths.

Manuring.—Blackcurrants cannot be manured too liberally. They thrive best on annual dressings of dung supplemented by nitrogenous fertiliser. Where dung is unobtainable well-rotted compost made from vegetable waste, straw or straw-composted domestic sewage sludge may be applied instead, but with these materials the addition of a complete N.P.K. fertiliser may be necessary and the nitrogenous dressing may have to be at a high rate.

Dung and other bulky manures may be applied any time during the winter and the general practice of spreading the material along the rows or around the bushes after hoeing out any autumn weed seems most satisfactory.

Where compost is used, a complete fertiliser such as 2 to 5 cwt. sulphate of ammonia or nitro-chalk, 1 to 2 cwt. muriate of potash, and 2 to 3 cwt. superphosphate per acre should be applied broadcast along the width of the rows in early spring.

Pest and Disease Control.—The most important pests are aphides, green capsid and big bud mite, although of recent years blackcurrant midge has appeared in many parts of the country. Reversion and leaf spot are the two chief diseases.

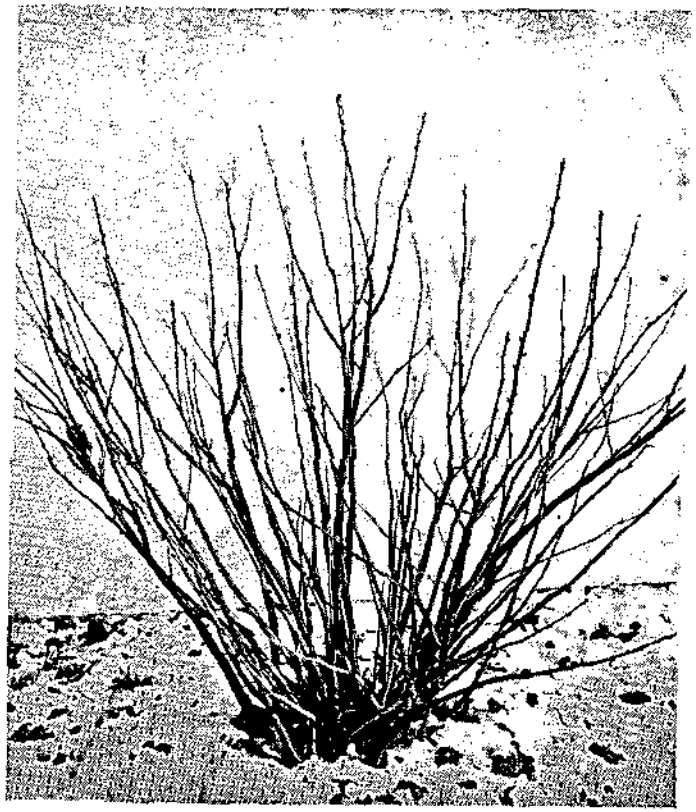
Fortunately, all pests excepting big bud mite can be controlled by thorough winter washing with D.N.C.—petroleum at 7½ per cent. dilution applied during January or February. Both the shoots and the thick basal cluster of branches should be thoroughly wetted, and a fully-grown plantation will need up to 500 gallons of wash per acre.

Big bud mite can be controlled by lime sulphur spraying in spring when the tightly clustered flower buds first emerge. Unfortunately, however, this wash frequently reduces the crop, especially if frost follows spraying. The best policy is to plant only substantially mite-free bushes, to spray with lime sulphur at 3 per cent. dilution in the first year after planting and then to spray annually or every other year only at a dilution of 1 to 2 per cent.

Reversion, a virus disease, can be controlled only by rigorous elimination of affected plants and it is vitally necessary to start with clean nursery stock, to examine the bushes annually in June and to remove infected bushes.

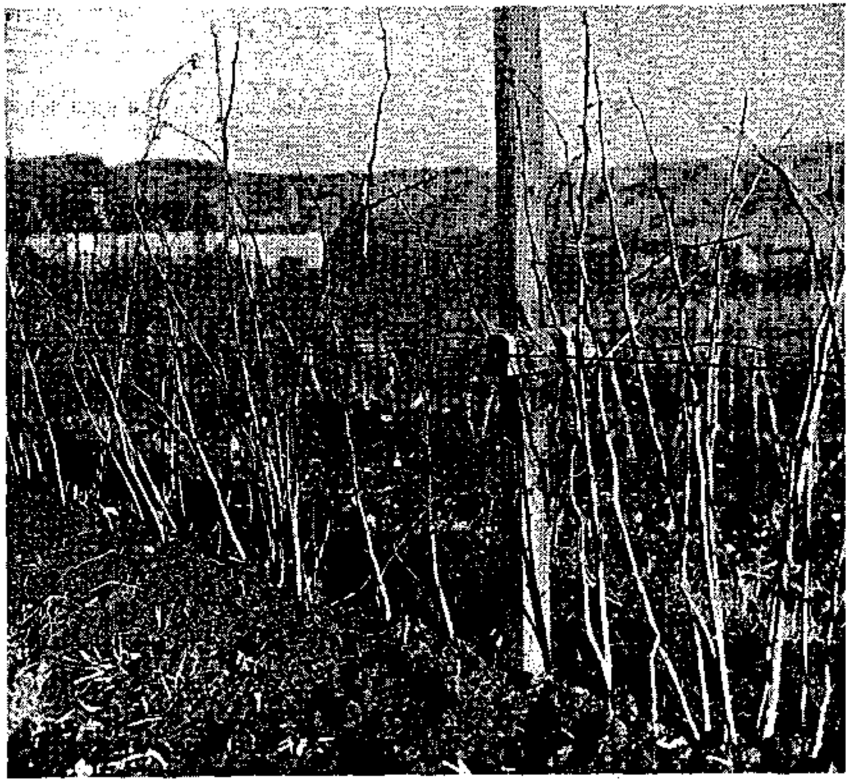
Leaf spot is not of general occurrence and the varieties Baldwin and Westwick Choice seem the worst affected. Bordeaux spraying, where necessary, is done immediately picking is finished. A spray programme for blackcurrants is as follows:

Blackcurrant—a useless type of bush grown on a "leg."



Blackcurrant—a well-grown bush.

(*Both by permission of Long Ashton Research Station.*)



Raspberry plantation.

Cherry tree on F 12/1 root-stock seven years after planting; variety Napoleon. Note grass cover.

(*Both by permission of Long Ashton Research Station.*)

Stage	Approx. time of spraying	Materials per 100 gals. wash	Pests and Diseases Controlled
Dormant	Jan. - Feb.	7½ gal. D.N.C. petroleum emulsion	Aphides, capsids, midge
Tight blossom cluster ..	early April	1-3 gal. Lime sulphur; ½ lb. wetter	Big bud mite
Immediately after picking	end July	Bordeaux mixture; 8 lb. copper sulphate; 8 lb. quick lime; ½ lb. wetter	Blackcurrant leaf spot

Harvesting.—Blackcurrant picking begins at the end of June or in early July, according to season, locality and variety, and is usually finished by the end of July.

The fruit is picked on the "strig" and should be firm and ripe. Too early picking with green tip berries results in complaints from the buyer, whilst over-ripe fruit quickly "mushes" and spoils.

Marketing.—For sale in the shops, the fruit is picked direct into 4 lb. to 6 lb. chip baskets, but for juice manufacture and the jam trade, fruit is usually picked into the grower's containers holding about 12 to 24 lb. After weighing and crediting to the pickers, the fruit is then poured into trays, tubs or the container supplied by the manufacturer.

RASPBERRIES

Raspberry growing should only be undertaken by the farmer who has a suitable light soil and a ready source of picking labour in June and July.

Planting Material.—Raspberry growing has declined greatly as the result of the devastations of virus diseases and many of the varieties once commonly grown have in consequence been lost to commerce. At present, only one variety—Norfolk Giant—is included in the Ministry of Agriculture's Certification scheme, but others may be added when virus-free stocks become available. Planters, therefore, are advised to plant only this variety so long as it is the only one available under the Certification scheme.[1]

Preplanting Cultivations.—Land intended for raspberries should be in a high state of cultivation and free from perennial weeds. Once

[1] Three varieties, St. Walfried, Malling Promise and Newburgh have now been added, and are available under the scheme.

cane is planted, cultivations can proceed in one direction only, and weeds such as couch grass can quickly establish themselves in the cane row and smother the plants.

Since the retention of summer moisture is important, as much organic matter as possible should be ploughed in before planting, and where dung or compost is not available, one or two cover crops should be ploughed under during the season prior to planting.

Planting.—Planting may be done any time from leaf fall to March, provided the soil conditions are suitable. Since heavy losses may occur if the roots are allowed to dry out between lifting cane in the nursery and planting out on the farm, purchased material should be "heeled" in or planted immediately on receipt.

Raspberries are usually planted in continuous rows and the width between rows must be adjusted to suit the available tools. Horse-drawn implements or small walk-behind tractors can work in rows six feet from centre to centre, but wheeled tractors need a minimum of nine feet between the rows.

On large areas, provision must also be made for a mobile spraying outfit to travel down the rows, and a 9-foot spacing is necessary for this purpose. Where horse cultivation is relied upon with closer spacing, cross-roads nine feet wide should be provided at approximately every 150 feet for the spraying machine, from which hoses will need to be pulled between the rows. The distance apart of cane in the rows should not be less than 18 inches. Since newly-planted canes should be cut down close to soil level it is a good plan to shorten all canes before planting, leaving just sufficient length (about 18 inches) for easy handling. The roots should be covered with a few inches of soil only and the soil well firmed. Planting may be done expeditiously in accurately drawn furrows, or on ground previously marked out, by two people working together, when one cuts the holes with a spade whilst the other carries a bundle of canes and sets one in each hole, treading the soil firmly after planting.

Cultivation.—All cultivations near the rows must be shallow, since raspberries produce masses of fine roots close to the surface. Deep cultivation increases the nuisance of "sucker" growth between the rows.

Hand cultivation, especially in the first two years, is unavoidable, along the cane rows and care must be taken to work the soil towards the plants.

Inter-row cultivation involves frequent spring tine-harrowing and scuffling throughout the spring and summer months. Disc-harrows should only be used on clean land and they must be set shallow and kept a full 18 inches or more away from the rows. In winter, the alleys are lightly ploughed towards the cane, leaving a shallow water furrow down the middle of each.

Winter cultivations should be carried out after the completion of pruning, spraying and mulching operations.

Cane Supports.—No support is provided by some growers, who shorten the cane each winter to about 2 feet 6 inches high, but it is often preferable to leave the canes longer and to provide support by string or wire along each side of the rows. Binder twine or 6-ply fillis is quite satisfactory if run along from frequent supporting posts, at about 2 feet 6 inches from the ground and on each side of the row, crossing the strings over one another at intervals.

Where wire is used, 16 gauge will be found suitable. It should be stretched from T cross-pieces on firmly bedded supports, the end posts being suitably strutted. The two wires should be set parallel and about 2 feet 6 inches above soil level, the new canes being placed between them at pruning time.

Manuring.—The need for ample supplies of organic matter has been stressed already, especially in the initial preparation of the land. In addition, an annual application of say 6 to 8 cwt. meat and bone meal, or 2 cwt. sulphate of ammonia (or equivalent), 3 cwt. superphosphate and 1 cwt. muriate of potash, should be given along the rows in March or early April after the first spring cultivations.

Pruning.—Pruning involves the cutting out of all fruited and weak canes at ground level and only strong new canes being retained. As the plantation ages, every effort should be made to keep the rows fairly narrow and the cane clumps separated one from the other. Pruning may be done any time after leaf fall, but the tipping back of new canes left for fruiting is best left until late winter or it may result in killing back by frost.

Pest and Disease Control.—The chief pests are aphides and raspberry beetle. A suggested spray control programme is set out below.

Stage	Approx. time of spraying	Materials per 100 gals. wash	Pests Controlled
Just before bud burst ..	from mid-March	$7\frac{1}{2}$ gal. D.N.C. petroleum emulsion	Aphides, raspberry moth
Full blossom	early June	Derris or Lonchocarpus dust	Adults of raspberry beetle
2-3 weeks after petal fall	mid-end June	Derris or Lonchocarpus; $\frac{1}{2}$ lb. wetter	Larvæ of raspberry beetle

Cane spot and verticillium wilt disease have seriously affected raspberry growing in some areas, but mosaic, a virus disease, is the most widespread, and the planting of virus-free stock is of fundamental importance. Even where this is done, however, mosaic may appear in the course of years. Should a marked dwarfing of the cane be noted,

together with a yellow mottling of the leaves which curl downwards, mosaic should be suspected. Individual infected clumps of canes should be dug out and no canes from the plantation taken for propagation.

Picking and Marketing.—Raspberries should be picked "firm-ripe" and except in special circumstances the fruit is "plugged," i.e. picked off the stalk.

Picking is best done at piece-work rates and supervision should be given to ensure that all well-coloured fruits are cleared at each picking, otherwise much good fruit between the canes, especially if low in the row, will be missed and become overripe before next picking.

Where the fruit is being sold for jam, picking is best done into 7 lb. cans, fitted with wire handles which are fixed to the waist by a belt or cord. For the fresh market very careful handling is necessary, and the fruit is picked direct into 1 lb. or 2 lb. chip baskets.

STRAWBERRIES

Strawberries are a short-term crop. Given good cultural conditions, a field may yield three or sometimes four crops before ploughing in. The crop, therefore, can fit in with rotational arable cropping on the farm and the growing of strawberries on a new site at each planting is sound practice. Apart from suitable soil and environmental conditions, the intending planter must be reasonably sure of sufficient labour during the picking period, which may extend from late May throughout June.

Site and Soil.—Since strawberries flower during April and May (the most critical months for spring frosts) and the plants flower close to the soil surface, the provision of a site reasonably free from spring frost is of great importance.

The best soil is a rich medium loam, high in organic matter, which has a good water supply during May and June, but which is well drained. Shallow soils and soils subject to waterlogging are unsuitable.

"Early" strawberry land occurs in the south and south-west of England and the steep shallow slopes of the Tamar Valley and of Cheddar are good examples of suitable conditions for early crops. Strawberries fruit, however, under less genial climatic conditions and main crops are successful in the main fruit-growing areas.

Planting Material.—It is vitally important to plant only virus-free material, since strawberries have suffered severely from these diseases. Special runner propagation nurseries have been established throughout the country where growers raise strawberry runners only, to the exclusion of fruit, for the supply of plants to the trade. The Ministry of Agriculture publishes annually a list of growers of certified stock, and intending planters should buy plants from such sources only.

Varieties.—Three varieties only are recommended for general use. They are Royal Sovereign, Madam Lefebvre, Huxley. Royal Sovereign

and Huxley are available in fair quantity from certificated nurseries. Sovereign is highly susceptible to and is quickly destroyed by virus diseases whilst Huxley and Madam Lefebvre are carriers which tolerate virus and continue to crop when moderately affected. Royal Sovereign should on no account be planted near either of these carriers.

Preplanting Cultivations.—Thorough and deep soil preparation before planting is necessary, as once the plants are in, cultivations must be shallow. The organic content of the soil should be high and this may be achieved by ploughing in heavy dressings of dung, compost or cover crops such as vetches or mustard.

Since strawberries require a firm bed, the main cultivations should be done in time for the soil to settle before planting, and if weeds are allowed to germinate they should be killed by harrowing once or twice before planting. A complete N.P.K. fertiliser should also be broadcast and harrowed in at this time.

Wireworm and chafer beetle may be serious pests of strawberries and it is unwise, therefore, to plant on newly-turned-in turf. Potatoes and roots are suitable crops to precede strawberries.

Planting.—Planting in the south-west is best done in August and September if plants are available, since the rainfall ensures quick establishment and a large plant in the first year. In the east, south and midlands, however, planting extends into October and November. Winter planting is not satisfactory and if autumn planting is not possible it is better to wait until March or early April. Spring plantings, however, may fail from droughts.

Planting is best done with a trowel, and care is necessary to plant firmly and deep enough to cover all roots and the base of the crown, but no deeper. Planting distances vary in different parts of the country, from 2 feet to 3 feet between the rows and 12 inches to 18 inches between the plants being common practice. The most important consideration is the provision of suitable spacing for the implements used for cultivation. Areas to be worked by hand and by pony are planted more closely than where tractors are used.

After Cultivation.—Weeds must be kept in check by frequent shallow cultivation in spring, and the ground should be quite clean before the development of fruit renders further cultivations undesirable until after picking.

As soon as picking is finished, the beds should be cleaned and the plants helped to grow rapidly and form new crowns for the next year's crop. Where straw is used for bedding the plants, it is good policy to shake it up over the plants and, when dry and a light wind is blowing, to burn it off, so clearing the ground of all rubbish and destroying old leaves and pests on the plants.

Autumn cultivations may finish on heavy soils by lightly ridging the plants with the double-breast plough in order to assist winter drainage.

Strawing.—The fruiting bed should be strawed to keep the fruit free from grit and soil. Barley straw is best for the purpose, but whatever straw is used it should be dry, clean and free from weed seeds. About one ton of straw is needed per acre (except with maiden plants). It should cover the whole width between the rows and should be tucked by hand underneath the fruit trusses and close up to the crowns. Strawing should not be done until the fruits weigh down the trusses and the work should always be preceded by a cultivation to kill weeds.

Derunnering.—Strawberry plants throw out runners freely and it is necessary to go over fruiting beds three or four times during the season to cut them off as they form. Where gaps are present, runners may be trained in to fill the spaces, and in the last cropping year all runners growing along the rows may be left in, only those growing across being cut away.

Manuring.—Provided the organic content of the soil is kept high, the plants usually respond well to annual dressings of a complete N.P.K. fertiliser with the nitrogen in organic form. High nitrogenous manuring should be avoided as it tends to produce leafy plants, prone to mildew attack and to promote weed growth. Unless heavy dressings of dung have been given, potash applications will be necessary, and since the strawberry seems very sensitive to phosphate deficiency, superphosphate should be applied each year.

A suitable annual dressing is as follows: Meat and bone meal 6 to 8 cwt., sulphate or muriate of potash 1 to 2 cwt., superphosphate 1 to 2 cwt. per acre. Where inorganic nitrogen is used: sulphate of ammonia 1 to 2 cwt., sulphate or muriate of potash 1 to 2 cwt., superphosphate 3 to 5 cwt. per acre. These fertilisers should be applied in early spring after the first cultivation.

Pest and Disease Control.—Wireworms and chafer beetle larvæ have already been mentioned as pests of newly-planted strawberries. Rootweevils (clay-coloured weevil) sometimes infest and destroy older beds. Aphides are serious pests in that they spread virus diseases, and tarsonemid mite can quickly render a bed unprofitable. Newly-purchased runners should be dipped in nicotine solution before planting out.

Mildew and grey mould (botrytis) are the most general fungus diseases and will be found most troublesome where plants are too thick or leafy and in wet seasons. Red core, a root-rot disease, has caused severe losses in some areas, notably in Lanarkshire, where it is termed "Lanarkshire Disease." Since the disease can remain in the soil for many years and there is no known cure, it is very important to buy runners from a clean source. Rotating strawberries round the farm is an additional precaution. The grower should be able to recognise virus diseases, since even with a clean start, virus is almost sure to appear at some time or other, and the grower is advised to keep in touch with his Fruit

Advisory Officer and to "walk" the strawberry fields in his company several times during the growing season.

The following spray programme may be necessary to keep fruiting beds of strawberries free from mildew, red spider and aphides:

Stage	Treatment	Pests and Diseases Controlled
Before planting ..	Dipping; 6 oz. nicotine per 100 gals. water, 1 lb. wetter	Aphides
Early May (before flowers open) ..	Sulphur dust	Mildew and red spider
End of May ..	Sulphur dust	Mildew
End June (after picking) ..	$1\frac{1}{2}$ gal. lime sulphur; 1 lb. wetter, 6 oz. nicotine per 100 gals. water	Aphides, red spider, mildew

Picking and Marketing.—The picking season begins in late May or early June and is a short one, lasting from fourteen to twenty-eight days according to the varieties grown and the season. The fruit is picked intact on the stalk except when jam strawberries are being cleared.

The beds need picking over daily or on alternate days according to the variety and the weather, and the work is usually undertaken at piece-work rates by female or gipsy labour.

The fruit is picked direct into small chip baskets holding 1, 2 or 4 lb., and constant supervision is necessary to ensure that no picker resorts to "topping" the baskets. The fruit should be firm-ripe, half-coloured being a good stage of ripeness to stand transit, and only sound, undamaged fruits should be included. Very small fruits are usually left on the plants to be picked later for jam. Some growers sell the bulk of their crop through wayside markets, but where distant transit is necessary, the fruit should be picked early and dispatched whilst cool. Extremely careful handling is necessary at all stages if the fruit is to arrive at its destination in a satisfactory condition.

CHAPTER 7

HOP GROWING

By F. H. Beard

Although hops occupy only a very small proportion of the country's arable acreage (about 20,000 acres) and are grown in only a few areas, they are of great economic importance. There are few, if any, agricultural crops with a higher market value. At the present time, the value of the finished product is around £23 per cwt. and the yield from a good garden should be at least 18 cwt. per acre. Costs of production are correspondingly high. No present-day figures are available, but pre-war capital cost of wirework was around £60 per acre with a life of about twenty years. Where not already in existence, an oast would be needed, costing £2,000 and upwards, according to size. The heaviest annual cost is for picking and drying, which Parker[1] gives as around £37 per acre out of a total expenditure of £95 per acre, but he considers these figures to be on the low side, and totals of from £120 to £140 per acre would be more usual. At one time hops were a very speculative crop, but at the present time, owing to the operation of the Hops Marketing Board, the grower is assured of reasonable returns. The Board allocates a quota of so many cwt. to each grower (or farm) who grew hops during a basic period. New growers must acquire a quota from someone not wishing to use theirs. The quotas allocated are increased or decreased, according to the demand for hops.

Situation and Soils.—Hops are quite hardy under English conditions, but they need a dry and warm summer to ripen their crop. Such conditions exist south and east of a line drawn approximately from the Wash to the Bristol Channel, although the successful north-midland area is north and west of this line. The fact that hops are now only grown in a few districts must be attributed to the very specialised nature of the crop. The selected site must be well protected from winds by either natural or artificial shelter. Hops can be grown on sites which would be too much of a "frost pocket" for fruit. Most varieties do best on deep, well-drained loams, but one variety, the Fuggle, prefers a rather heavier and moister soil.

Varieties.—At the present time 75 per cent. of the English acreage is devoted to the Fuggle, a hardy, good cropping hop, which is easy to pick and of fair quality. The remaining acreage is largely made up of "Goldings" and "Golding Varieties." Goldings are the choicest English hops as regards aroma and flavour, but are more difficult to pick, owing to their smaller cones and more leafy growth. They succeed only on the

[1] "The Hop Industry." H. H. Parker, 1934. P. S. King & Son, London.

best soils and are chiefly grown in East Kent and the Teme Valley in Worcestershire. There are a number of Goldings, but as they have all arisen as selections from an original parent type, they differ only slightly, apart from time of ripening. "Golding Varieties" (Cobbs and Tutsham) have bolder cones and hardier constitutions than the true Goldings, but are of poorer quality. Some thirty to forty years ago Professor Salmon, of Wye College, Kent, started breeding new varieties of hops, and by utilising the wild American hop (*H. americanus* Nutt.) has raised a number of varieties of much greater brewing value than the older varieties. These new varieties are now rapidly coming into commercial cultivation in this country and in America. The ones most planted at the present time are Brewer's Gold, Bullion Hop, College Cluster, Malling Midseason and Early Promise.

Male and female flowers of the hop are borne on different plants. All varieties are female, but male plants (1 in 200) of the correct season are needed for pollination. Virus diseases are of great importance in hop growing, and in practice, varieties fall into two groups: those that are susceptible to mosaic disease and those that are tolerant carriers. These two groups must never be planted in close proximity. Care should also be taken that mosaic-tolerant males are not planted in gardens of susceptible varieties.

Propagation.—Hops are true perennials, but under commercial conditions a certain amount of annual replacement is needed, due to the incidence of diseases. If diseases are controlled the garden may continue to yield for forty years, but otherwise may need grubbing after twenty years or less. Hops are normally propagated by planting cuttings made from the swollen bases of the past season's growth (see "Dressing"). Rooted sets for planting out are obtained by growing the cuttings 4 inches apart, in rows 2 feet 6 inches apart, in a nursery for a season. Support (about 4 feet high) is needed for the bines of the nursery plants. Owing to the prevalence of disease in most established gardens, it is now recommended that hops be propagated intensively by layering from a small and carefully rogued parent garden. It even seems desirable to establish special nurseries for the propagation of disease-free material. Although there is more than one method of layering, the basis of all techniques is to cover selected bines with soil during the growing season and at the end of the season to uncover them and cut them into suitable lengths each with a node. These "cuttings" are planted in a nursery as described for the ordinary cuttings. By layering, a single parent plant will produce annually about fifty cuttings, compared with five to eight by the older method.

Planting.—The ground is marked out with small sticks as for planting fruit trees or bushes. Planting can be done any time between November and April, but should be completed by the end of February if possible. Rooted sets are generally used. A small hole is dug to accommodate the

set and the soil well firmed after planting. The top buds of the set should be just below the soil surface. Some growers plant cuttings direct into the garden using two or three to a site. These are best planted with a dibber.

Distance of planting should be varied to suit the variety. On most soils a 6 feet square plant suits Fuggle, whilst 8 feet square would not be too great for Brewer's Gold or Bullion Hop. It is best to err on the side of too wide spacing and so avoid the condition known as "housed in."

Systems of Training.—Established hops are now always grown on a system of permanent poles and wires to which coir yarn is fixed annually to support the bine. The system most popular at the present time is the "umbrella" so called from a fancied resemblance of the strings to a partly open and inverted umbrella. The popularity of this system is due to the absence of any low wires, which permits cross cultivation and hence reduces hand labour to the minimum. Poles (12 to 14 feet above ground) are usually set by every sixth hill.[1] Overhead wires cross at right angles over each hill. A wire skewer is placed by each hill and from this four strings are taken to hooks on the overhead wires above the adjacent hills. The strings are loosely tied together about 3 feet 6 inches from the ground to facilitate cultivation. Umbrella wirework needs stout outside poles and good anchorage or there is a danger of complete collapse. Unless the grower has men skilled in the work it is usual to employ a contractor.

Dressing.—In order to restrain the naturally rambling nature of the plant and to form a compact crown from which the strings can be furnished, the hills must be "dressed" or pruned each season. In the early spring the soil is removed from around the hills, and the bases of the previous season's bines, together with any runners, are cut hard back to the crown. As the hop cannot form buds on its roots care must be taken when dressing young plants to avoid cutting back into root tissue.

Seasonal Training Operations.—With the object of obtaining the most fruitful type of growth, the more forward bine is removed in May and the strings furnished with shoots of suitable vigour. The choice of bines depends on the vigour and age of the plants, and forwardness of the season. Two bines are usually put to each string, but with very vigorous varieties one bine is enough. After the strings are furnished the surplus bines are removed. Continued training is needed to keep the bines to the strings. When the bines have made about 4 feet of growth the lowest leaves are removed, and when growth reaches the top of the strings, leaves and laterals are removed from the bottom 4 feet. After stripping, a few shovelfuls of soil are placed to each hill. This prevents the formation of further shoots and makes the dressing of the hills easier.

Cultivations.—The annual cycle of cultural operations begins in late summer or in autumn after picking. On heavy land the alleys are baulked up at the end of August with an implement like a miniature snow-plough, and then left until early spring when the land is ploughed away from the

[1] Each plant set out in a hop garden is known as a "hill."

hills. On the lighter soils the land is ploughed towards the hills in November and back to the centre of the alleys in early spring. During spring and summer, surface cultivations are carried out with discs or tined cultivators to maintain a tilth and destroy weeds.

Manuring.—Hops need generous manuring. Annual dressings should supply 350 lb. Nitrogen, 200 lb. Potash (K_2O) and 230 lb. Phosphoric Acid (P_2O_5). Best results are obtained by a combination of bulky organic manures (dung, shoddy, etc.) supplemented by inorganics such as Sulphate of Ammonia[1], Sulphate of Potash and Superphosphate. Except on soils with a high lime content, adequate dressings of lime are needed. Dressings equivalent to $\frac{1}{2}$ to 1 ton quicklime may be given every four years.

Picking.—The crop is usually ready for picking from the beginning to the middle of September according to variety and district. Ripeness of the cones is indicated by their becoming crisp to the touch, the presence of the valuable resins (making them sticky when rubbed up in the hand), the firmness of the seeds, and by a colour change to a more mellow green.

In picking, the bines are first pulled down. A sharp pull on the string causes it to break from the wire; the cones are then stripped from the bines into baskets or bins according to local custom. Payment is at the rate of so many "bushels" per shilling. A good picker can pick 15 to 30 bushels a day, according to the variety. Picking is still largely done by hand, but a few large growers are using machines experimentally.

After picking, the bines are left to die down naturally and in early November they are cut off at ground level and either burnt or cut up for use as litter in bullock yards.

Drying.—Green hops may contain as much as 80 per cent. of water and this must be reduced to about 6 per cent. in order that they may be stored. This is done by passing a current of hot air through the mass of green hops. The drying of the crop is carried out in an Oast House, consisting of one or more kilns, together with packing and storage space. Until comparatively recent times drying was largely a matter of acquired skill, but, as a result of investigations by Dr. A. H. Burgess of Wye College and the introduction of modern heating installations, it is now much easier to obtain a satisfactory finished product. The essential features of a kiln are a slatted floor on which rests a loosely woven, horse-hair cloth to receive the hops, and means of producing an adequate volume of hot air. Drying should be carried out at as low a temperature as possible, but owing to the need for having two loadings in each twenty-four hours the maximum temperature is usually around 140° to 155° F. The commencing temperature must not be higher than 110° F. with a good draught (90° F. with a poor draught) as the hops will be spoilt if they get heated whilst the petals are still moist. Roll brimstone, at the rate of $\frac{1}{4}$ oz. for each 1,000 cubic feet of air passing through the kiln during the first hour, is burnt below the hops to improve their colour and aroma. The maximum loading depends mainly on

[1] Applied at three times: early April, mid-May and end of June.

the air-speed. The air-speed (feet per minute) multiplied by 0·8 gives the depth of loading in inches. The hops are sufficiently dry when the "strig" or central axis of the cones is dry and handles like a piece of string. The dried hops are allowed to cool on the kilns for a short while and are then removed and placed in large covered heaps for as long as possible. This operation causes a redistribution of moisture between over- and under-dried cones and enables the hops to be packed with least damage to the cones. The hops are finally pressed into circular bags holding $1\frac{1}{2}$ cwt. and known as "pockets."

Pests and Diseases.—Hops are subject to attack by many pests and diseases but only three pests and six diseases are generally troublesome. The sprays and dusts needed for their control are applied by specially designed machines.

The Hop-Damson Aphid (*Phorodon humuli*) or "blight" is nearly always in evidence and if not checked will destroy the crop. Fortunately, nicotine preparations give good control. Nicotine and soap spray (4 to 6 oz. nicotine per 100 gal.) is best, but dusts may be used if more applications are given.

Flea beetle (*Psylliodes attenuata*) often seriously damages the young bines by feeding on the leaves or tips when cold and dry conditions prevail in the spring. A derris or proprietary flea-beetle dust should be applied. Red Spider (*Tetranychus telarius*) is not such a widespread pest but it causes damage in some gardens, particularly in dry seasons. The attack is initially on the undersides of the leaves, but unless checked it spreads to the cones turning them a reddish brown. Control is by removal of lower leaves (see "training") and applications of 1 per cent. lime sulphur sprays at the end of May or early June. Later sprayings may be given but tend to clash with copper sprays for control of downy mildew.

Mould (*Sphærotheca humuli*) commences as white powdery patches on the leaves and if not checked, later attacks the "burr" (flowers) and cones, completely destroying the crop. The disease *must* be checked in its *early stages*. Control measures consist of removal of lower leaves and frequent dustings with sulphur from early June onwards. Where mould has been severe in the previous season, dustings should be given fortnightly from the end of May until August, but normally, unless infected leaves are noticed, an early and late dusting should be adequate.

Downy mildew (*Pseudoperonospora humuli*) is a relatively new disease, first noticed in Japan in 1905 and in England in 1920, and is now found in nearly all hop-growing countries. It is a "wet weather" disease. In the spring and summer the fungus causes characteristic stunted and yellowish shoots, known as basal, lateral or terminal "spikes" according to their position. It also causes dark angular spots on the underside of the leaves, and may later attack the "burr" and cones, causing a complete loss of crop. In some cases the "straps" and rootstock are attacked and killed. Control measures consist in the prompt removal of spikes in spring and early summer combined with the prompt stripping of the lower leaves. Protective

copper-containing sprays are given (1) when bines reach the top wire, (2) just before flowering, (3) just after flowering. In dry seasons the first spray may be omitted and in wet seasons a spray should be given when the bines are three-quarters up the strings. Bordeaux mixture (10 lb. copper sulphate, 15 lb. hydrated lime, 100 gal. water) gives the best protection.

Verticillium wilt (*Verticillium albo-atrum*) is another new disease, first recorded in 1924. It is diagnosed by a light brown discoloration of wood in affected bines, usually extending upwards for several feet.[1] There are two forms of the disease: (1) fluctuating type, usually not serious, many hills may be affected, but only a few are killed, and the intensity of attack varies from year to year; (2) progressive type which spreads rapidly and may soon destroy the whole garden. Dying bines appear from June onwards. The ground remains infected so that replanting with the existing variety is useless. The only "cure" lies in the planting of resistant varieties which are now being developed. Though the progressive type is disastrous for the grower who has it in his garden, it is at present confined to a limited area in Kent.

"Nettlehead" is a virus disease, widespread in Fuggle gardens and probably causes the greatest annual loss of crop. The symptoms are *upturned* margins of the leaves, and failure of the bines to climb the strings. As warm weather tends to mask the symptoms, affected hills are best seen just before training time. Control measures consist in grubbing affected hills and propagating only from healthy gardens. Care should be taken when planting a new garden that material comes from a reliable source.

Mosaic is another virus disease which affects only Goldings and "Golding Varieties." Leaves are mottled with *down-curved* margins whilst the bines fail to climb and may die back from the tips. Affected hills usually die within two years. Control is as for Nettlehead, with the additional precaution of not planting "carrier" varieties (Fuggle and new varieties) near susceptible varieties. Care should be taken that any males planted are not "carriers."

The risk of trouble from the virus diseases can be greatly reduced by planting material from a reliable source, certified by the Ministry of Agriculture, who issue a list of certified gardens annually.

Wye College and East Malling Research Station have functioned as centres of Hop Research, and advice on all aspects of Hop Growing may be obtained by applying to those centres through the local N.A.A.S. Officer.

[1] No other disease causes discoloration for more than 1 foot.